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Mental Muscularity:
Shaping Implicit Theories of Intelligence via Metaphor

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Mental Muscularity:
Shaping Implicit Theories of Intelligence via Metaphor

by

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Dissertation

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Doctor of Philosophy

The University of Texas at Austin

August 2009

Dedication

To Providence and Family,

My wife Brittany, our children, and Dan and Linda Anderson.

I am a Victor only because of you.

What a journey this is!

Acknowledgements

My life has unfolded in ways I never expected. At each moment when a new phase of my life began, it was inevitably one or two people who impressed me to the degree that my life's course would never be the same again. I pause now to acknowledge those who have stretched me in a particularly favorable fashion: First, to my wife Brittany, and kids, Mckay, Taylor, and Benson, for being my anchors to what really matters in life; Second, my family, and especially to my parents, Dan and Linda Anderson, for a lifetime of exemplary living and encouragement; Third, to Matt McGlone, a wise mentor, a constant voice of encouragement, and a standard of academic excellence and intellectual curiosity. Thanks for your kind refinement and for helping me in my growth process. Finally, there have been so many others along the way, from friends, to Church leaders, to colleagues, to teachers, to professors, too many to count. To L. Edna Rogers, Mary Ann Sontag-Bowman, and Anita Vangelisti, thanks for being brilliant, inspiring, and wonderfully real.

Mental Muscularity:

Shaping Implicit Theories of Intelligence via Metaphor

Publication No._____________

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The University of Texas at Austin, 2009

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Motivating students is a central challenge for many teachers, particularly in subjects students commonly perceive as “impenetrable,” such as statistics. One line of motivation research by C.S. Dweck (2006) has found that when students believe their intelligence is malleable (i.e., a growth mindset) and that learning is a function of effort, they show greater motivation, accept more learning challenges, and have improved performance outcomes relative to students who believe their intelligence is fixed (e.g., “I’m not a math person”). This dissertation extends research regarding implicit theories of intelligence by examining how metaphors of the growth mindset (e.g., the mind is a muscle) can be integrated as feedback into a computer program to encourage students to implicitly adopt the growth mindset relevant to statistics. The present study manipulated framing conditions with metaphorical, literal, and no feedback about the growth mindset. Results show that framing feedback implicitly in terms of the “mind as muscle” metaphor increased non-math major undergraduates’ willingness to accept learning challenges and their overall score on testing items relevant to statistical literacy, as compared to students who received literal feedback or no feedback about the growth mindset. Also, overall, gender differences were noted, with males accepting more learning challenges, passing on fewer difficult items, and having higher scores on testing items than females. Findings also indicate that participants' psychological reactance and interest in fitness and muscularity (metaphor resonance) did not meaningfully change participants' learning outcomes.

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CHAPTER 1: RATIONALE

In Trento, Italy, a Da Vinci High School student did not have to complete a required math course because a judge ruled she was incapable of learning math (Lyman, 2003). The judge determined that Viviana would be able to start her senior year, even though she had failed a math course during her junior year. Under normal circumstances, a student would not be advanced to the next grade without successfully passing the previous courses. However, according to her lawyers, Viviana's circumstance was different. Specifically, they argued that she had an "irreversible psychological pathology"—a math phobia—that made it impossible for her to study and learn math. Although she had done well in other subjects, her lawyers argued that math was one subject that she was not capable of learning, and the judge agreed.

While the court ultimately agreed with Viviana's lawyers and granted her the grade advancement, the decision was met with resistance. The ruling was criticized by individuals who believed that content mastery should not be discarded because a topic is difficult. These critics also believed that alternatives should be found to teach those who struggle in a particular area, and that setting such a precedent was harmful for other learners who might make similar claims.

Viviana's story may be an extreme example of challenges in learning math, but the account highlights important issues beyond this subject matter. The controversy surrounding the court's ruling illustrates people's different beliefs about the nature of human learning, and brings to light a fundamental question: Are people really born smart or deficient in a particular area, or can anyone become smart given enough effort and persistence?

While admittedly important, the question above is perhaps not the most critical question we can ask about learning. According to Stanford psychologist Carol Dweck (2006), rather than asking a generalized question about what is intellectually attainable, the most beneficial question may be the one that is the most personal: What do *you* personally believe about *your* intelligence? As the result of substantial research conducted over the past 35 years (Diener & Dweck, 1978; Dweck, 1975, 1992; Dweck, Chi-yue, & Ying-yi, 1995; Dweck & Elliott, 1983; Dweck & Reppucci, 1973; Dweck & Leggett, 1988; Elliott & Dweck, 1988; Hong, Chiu, Dweck, Lin, & Wan, 1999), Dweck has found that the tacit beliefs people have about their own intelligence—their implicit theories of intelligence—largely determine the motivation, effort, goals, and outcomes they have during the process of learning.

Viviana's lawyers argued that she was incapable of mastering math. Her psychological condition was diagnosed as "irreversible," indicating that improvement was unlikely and perhaps impossible. Although news reports did not directly report Viviana's beliefs about her own intelligence, it is likely that Viviana agreed with the lawyers' assessment. In many respects, Viviana may represent several people who believe that learning a particular subject—math, foreign language, physics, computers, or a number of other subjects—is impossible. They may believe they cannot learn certain subjects because they weren't "born with the brains" to do so.

When people believe their ability to learn a particular subject is limited and unchangeable, they demonstrate what Dweck calls the entity theory of intelligence, or the “fixed mindset.” The learning outcomes, as with Viviana, are generally negative when people have this mindset. For example, research has shown that individuals with a fixed mindset tend to avoid learning challenges that are difficult (Elliott & Dweck, 1988; Hong et al., 1999), become disinterested and bored in learning, and, in some cases, simply give up when a learning activity isn’t easy (e.g., Diener & Dweck, 1978). When trying to explain to themselves why they failed, they are more inclined to attribute failure to lack of ability than to a lack of effort in the subject that troubles them (e.g., "I can't do math"; Diener & Dweck, 1978; Dweck & Reppucci, 1973). Also, people with the fixed mindset are concerned with how others will evaluate their competence (Elliott & Dweck, 1988), a concern which leads them to avoid learning challenges, even when they recognize the benefits of learning the particular subject (e.g., Hong et al., 1999; Elliott & Dweck, 1988). To not appear incompetent, they stick to comfortable subjects where their ignorance will not be exposed. In the end, aversion to intellectual challenge subdues their learning potential.

Viviana’s case, however, is not just an example of the fixed mindset. Educators, including a developmental psychologist with Rome’s Sapienza University, and the president of the National Council of Teachers of Mathematics, believed that it was possible for her to master math, in spite of great challenges. They argued that with effort, motivation, and different teaching techniques, Viviana could overcome her challenges (Lyman, 2003). Like those who disagreed with Viviana’s decision, many people may also believe that anyone can master any subject, given enough work and persistence. They believe that learning is a function of effort and is always possible with enough dedication. When people believe their own learning is principally a function of effort, they are exhibiting what Dweck labeled the incremental theory of intelligence, or the "growth mindset." In contrast to the fixed mindset, the growth mindset is associated with the acceptance and pursuit of intellectual challenges, greater motivation and effort when faced with these challenges, and sustained or improved performance following failure (Dweck & Reppucci, 1973). People with the growth mindset are more concerned with *improving* than *proving* their competence to others in a given subject (Elliott & Dweck, 1988). Consequently, they do not worry about looking incompetent in front of others because they realize that acknowledging what they do not know helps them understand the material better, which is their main goal. Additionally, rather than being concerned with other's perceptions if they fail, they view failure as a cue to develop more effective learning strategies and a necessary part of the learning process (Dweck, 1975). In fact, they may not even perceive poor performance as "failure," but rather as an indication that they *are* learning and need to develop new strategies to understand and master the material they are studying (Diener & Dweck, 1978).

Consider then how Viviana's case may have been different if she had a growth mindset. Yes, math would still be hard. But in place of believing that she was incapable of doing math, she would think that effort and persistence can bring about mastery of the subject matter. Rather than despairing about the teacher's feedback on a test or assignment she didn't do so well on, she would have hope that subsequent practice based on the feedback would eventually bring success. She might also cultivate curiosity in the subject, wanting to know what makes formulas work, why math is so important, and how it can be applied to real-world problems. Evaluations, such as grades and what her peers or others might think of her, would become secondary to learning. She would not be afraid to ask questions in class (and perhaps risk looking foolish) to figure out what she wanted to know. With this mindset, she would be motivated to continue learning, and with time and corrective feedback, would develop mastery of math.

While the portrayal of the growth mindset may seem idealistic, the results of the research strongly support the claim that when students attribute their outcomes in learning to their effort, they are more motivated to learn than those who hold a fixed mindset, and exhibit superior learning performance (Diener & Dweck, 1978; e.g., Dweck, 1975). Given the positive outcomes associated with the growth mindset, what can teachers do to encourage students to adopt this growth mindset and improve their learning? One field that is principally interested in strategies for promoting effective learning is instructional communication. In its roughly 30-year history, research in this communication subfield has examined a variety of student-centered variables (e.g., willingness to communicate, communication apprehension, shyness, and self-perceived communication competence) and teacher-centered strategies (e.g., nonverbal immediacy, clarity, assertiveness, responsiveness, and use of power and influence in the classroom) that have a direct impact on student motivation (L. McCroskey, Richmond, & J. McCroskey, 2002). In particular, the construct of nonverbal immediacy (characterized by a sense of psychological closeness developed from behaviors such as eye gaze, smiling, and posture), has been highly related to student motivation, learning behaviors, and learning outcomes. For example, Witt, Wheeless, and Allen (2004) conducted a meta-analysis of 81 studies regarding immediacy and student learning, and found an overall positive and substantial relationship between the two constructs. Instructional communication has certainly offered valuable insights and effective strategies for improving student motivation in learning. To date, however, instructional communication researchers have not considered how implicit theories of intelligence affect student motivation or the teaching strategies instructors might use to encourage adoption of the growth mindset. In light of the positive findings associated with implicit theories of intelligence and learning motivation, such consideration is merited.

How can implicit theories of intelligence be integrated into instruction, and more specifically, into instructional materials? Would Viviana's outcomes have been different if she had been exposed to materials that encouraged the growth mindset? What strategies could instructors use to encourage people like Viviana to willingly adopt the growth mindset? These questions are the focus of this research.

Purposes of dissertation

How can students learn more effectively, and what can instructors do to facilitate that learning process? Researchers in both instructional communication and learning motivation have identified specific strategies that teachers may implement to ultimately improve learning outcomes. The first purpose of this study is to bridge the gap between these research traditions.

A second purpose is to consider the role that metaphor might play in messages designed to promote learning motivation. Although education researchers have been concerned with matters of motivation in the learning environment, they have not investigated the effectiveness of different linguistic and visual strategies that may be used to symbolically encourage motivation in the learning process. Specifically, neither line of research has examined how teaching materials can integrate metaphors that implicitly reflect and encourage the growth mindset (e.g., the mind is a muscle). This project addresses this issue.

Metaphors

What advantages do metaphors have over literal explanations in teaching and learning? Some language theorists have argued that metaphors are dangerously ambiguous, and thus might lead students to make erroneous inferences about concepts that are metaphorically encoded (Donnelly & McDaniel, 1993; Ortony, 1975). Although metaphorical language has its pitfalls, it nonetheless retains an important place in teaching and learning. Beyond the simple use of metaphorical language as an aesthetic linguistic ornament, metaphors are integral and necessary in instructional communication. Ortony (1975) articulated metaphor’s virtues as an educational strategy. First, metaphors provide compactness, or the transmission of large amounts of information with an economy of words. Compactness is essential in teaching and learning because instructors and students may not have the resources—in literal language, time, or capacity—necessary to explicitly detail or understand every fine point of instruction. Second, metaphors help teachers to bypass inexpressibility, or the inherent inability of any language to adequately describe subjective thoughts or experiences. When teachers do not have the right words to explain a concept, they must rely on metaphors to “fill the gaps” of what they cannot explain. And, finally, Ortony proposes that metaphors are necessary to teaching because they provide vividness, or a more complete mental representation of actual experiences, which then promotes greater understanding and memorability. While literal language limits what can be described (i.e., inexpressibility), metaphors can transfer inexpressible emotions and perceptions associated with the original experience in a more holistic, vivid representation that is retained by the learner for later recall. In short, metaphors are central to learning because of their compactness, inexpressibility, and vividness functions.

Explanatory versus motivational metaphors

Because metaphors are essential to teaching and learning, their use in teaching has been widely advocated by scholars (e.g., Daly & Vangelisti, 2003; Weinstein, Meyer, Husman, Stone, & McKeachie, 2006). According to Petrie (1979), metaphors are "one of the central ways of leaping the epistemological chasm between old knowledge and radically new knowledge" (p. 440). When instructors use metaphors to explain a new concept in terms of a previously understood concept, they are using what I call “explanatory metaphors.” Explanatory metaphors tend to be limited to application of a specific principle. For example, describing light waves by comparison to an oscillating jump rope might be appropriate for a physics professor, but the same metaphor is likely to be irrelevant for a history teacher. Also, explanatory metaphors are product-driven (as compared to process-driven), in that they are seen as the vehicle to directly bring the learner to the endpoint of understanding a new concept. Thus, if the oscillating jump rope metaphor increases understanding of light waves, the metaphor has served its function. Principle-specific, product-driven explanatory metaphors seem to be what most teachers think of when they consider the usefulness of metaphors for learning.

However, metaphors can also serve a motivational function. "Motivational metaphors" are distinct from explanatory metaphors in that they are not specific to any principle and are oriented toward motivating students in the learning *process*, which then improves the likelihood of achieving the learning *product*. The process of learning—comprised of difficulty, challenge, effort, persistence, et cetera—is universal and applicable to any topic or context. Consequently, the value of motivation in learning is also universal. Certain metaphors can promote learning by framing the learning process in a way that attracts students' interest and/or calms their anxieties. As a simple example, consider the learning process within the context of the old African adage of how to eat an elephant—one bite at a time. Such a comparison may help a student of *any* subject feel less overwhelmed with a particular learning task and may encourage the student to parse the task into manageable portions. The metaphor may improve the student's confidence in his or her ability to accomplish the task, increase motivation to keep at the task, and encourage the use of more effective learning strategies. By using a metaphor that highlights particular aspects of the learning process, students may experience more motivation than they would if the process were not represented at all, or if it were presented in purely literal terms.

Given that motivational metaphors are specifically about the learning process, they are an ideal vehicle for promoting implicit theories of intelligence. In particular, metaphors that emphasize the relationship between effort (e.g., equating physical exercise with study) and outcomes (e.g., equating stronger muscles with better learning) may also facilitate adoption of the growth mindset because the growth mindset is about the relationship between effort and outcomes. This area of convergence is the primary focus and contribution of this dissertation.

The "mind as muscle" metaphor

To examine the convergence between metaphors and the growth mindset, I assessed the use of a particular metaphor of growth—intelligence as muscle—as a form of performance feedback. By integrating this metaphor into learner's performance feedback, I hoped to symbolically represent and encourage the effort and persistence that are necessary for learning to occur. By using a metaphor that emphasizes the relationship between effort and outcomes, learners should adopt the assumptions of the metaphor, which are also the assumptions of the growth mindset. That is, by equating learners' responses with muscularity, learners should be inclined to adopt many other relevant characteristics (e.g., persistence, patience, and effort) associated with the metaphor. As a result of adopting the metaphorically-induced growth mindset, learners should then show the attendant positive learning outcomes—willingness to accept challenges, greater persistence when learning, and sustained or improved performance following failure.

This project evaluated the effectiveness of metaphor for encouraging adoption of the growth mindset. The medium for this evaluation was a computer program I designed for non-math major undergraduates to improve their statistical literacy, or their understanding of statistical information presented in everyday formats, (e.g., newscasts, advertisements, health brochures). To improve learning, the visual and textual feedback in this program were designed to promote acquisition of the growth mindset. Specifically, the different versions of the program presented testing items in a control condition with no reference to the growth mindset, a literal condition that encouraged the growth mindset through literal linguistic and visual feedback, and a metaphorical condition that encouraged the growth mindset through linguistic and visual components that metaphorically equated learning with the growth of muscles. Participants' reaction to challenge, learning persistence, and performance after failure feedback were used to compare the effectiveness of literal and metaphorical strategies for promoting the growth mindset.

Now that the rationales, purposes, and goals of this dissertation have been presented, a thorough review of the relevant literature will be presented along with the corresponding hypotheses. First, implicit theories of intelligence will be reviewed in greater depth, including research about the growth and fixed mindsets, and their associated thoughts, goals, behaviors, and outcomes relevant to learning. This will be followed by a discussion of metaphors, including the necessity of metaphors in teaching and learning, explanatory and motivational functions of metaphor, and metaphor resonance. Lastly, a more in-depth review of literature will be presented regarding how metaphors may bypass negative effects associated with learning about the growth mindset, and the context of statistics education and statistical literacy.

CHAPTER 2: LITERATURE REVIEW

Implicit Theories of Intelligence

One of the most influential theories in contemporary research on learning motivation is Dweck's implicit theories of intelligence (Dweck, 1992, 2006, 2007a, 1975; Dweck et al., 1995). Dweck has proposed that individuals have implicit beliefs about how intelligence works, and these beliefs determine the learning goals they will pursue and the motivation they exhibit when learning (Dweck & Leggett, 1988; Dweck, 2007b, 2006; Dweck et al., 1995). Her work has identified two broad classes of beliefs that people hold about the nature of intelligence.

The Growth Mindset

The belief that intelligence is changeable or malleable is known as the incremental theory of intelligence, or "growth mindset." Individuals with the growth mindset believe that outcomes in learning and intelligence are primarily a function of effort (Ames, 1992; Brophy, 1987; Dweck, 1986). Consequently, individuals with the growth mindset believe that persistence and effort will lead to improved intellectual capacities. Research has validated the positive outcomes associated with the growth mindset. For example, Dweck (1975) studied a group of 8 to13 year-old children identified by school officials as the "most extreme cases" of helplessness (characterized by expectations of failure and poor academic performance) to find out if attributing poor outcomes to a lack of effort, rather than ability, would improve the children's performance on math tests. The study consisted of two groups researched over a period of 25 daily sessions: a *Success Only* group, and an *Attribution Retraining* group. In the

Success Only group students were given tasks that were easy to perform, were rewarded solely for correct responses, and failure was "glossed over" by the experimenter. In the Attribution Retraining treatment, researchers created situations where students could not succeed (i.e., more difficult tasks), along with telling participants they "should have tried harder" following failure. Following the preliminary training tasks, the researchers initiated planned failure experiences in which all of the students were told that they had made incorrect responses or had failed to complete enough responses in a given amount of time. Student responses were measured both before and after the failure experiences. Results showed that students in the Success Only condition consistently declined in performance following failure experiences, while *all* of the students who had received training about attributions related to effort showed either improvement or maintenance of current performance. Not only did these students recognize the importance of effort, but the improvement in scores following failure also indicates that they engaged in more successful problem-solving. Thus, students who adopted the growth mindset responded to failure in a way that encouraged them to work harder and ultimately improve performance outcomes, whereas students who were not taught the same process had poorer performance following failure.

In addition to valuing effort, the growth mindset has also been found to orient learners toward goals of content mastery and competence development. Dweck and Leggett (1988) reasoned that when people believe they can change their intelligence, they have a different set of concerns than those who believe they cannot change their intelligence, and consequently, different learning goals. Dweck and Leggett proposed that individuals with the growth mindset are concerned with the goal of mastering content. In turn, the goal of content mastery positions the learner to respond more positively to failure in two ways. First, when students are motivated to master content, concerns about the evaluations of others become relatively unimportant. Taking risks in front of others—such as asking questions that may demonstrate ignorance, or failing at a task—is not considered threatening. Instead, such risks—if even considered risks at all—are considered necessary to the learning process because they help to clarify concepts that are not fully understood, and consequently, to improve subject mastery.

Secondly, failure at a task—which may not even be recognized as "failing" by those with a growth mindset (Diener & Dweck, 1978)—is not considered a reflection of ability, but rather a cue to develop alternative problem-solving strategies that can more directly achieve the goal of content mastery (Dweck & Leggett, 1988). Diener and Dweck (1978, Study 1) administered the Intellectual Achievement Responsibility (IAR) Scale (Crandall, Katkovsky, & Crandall, 1965) to 70 5th graders to determine whether they tended to attribute failure to their own efforts (i.e., the mastery-oriented growth mindset) or to external factors, including ability (e.g., an inability to do math). The IAR is a forced-choice questionnaire in which students are given the beginning part of a sentence (e.g., *If a teacher passes you to the next grade, would it probably be…*), then required to respond to one of two answers (e.g., *because she liked you* or *because of the work you did*). The students were then given a hypothesis-generating test, wherein the experimenters showed cards with different figures (e.g., alternating on color, forms such as triangle or square, and symbols such as stars or dots). Students were requested to look for the pattern (i.e., to test their hypothesis) that the researcher had in mind. The idea behind the measure was that students would develop a hypothesis (e.g., "I'm looking for all of the triangles"), test their hypothesis (i.e., seeking feedback from the researcher), and then modify or maintain their hypothesis based on the researcher's feedback. After establishing that the students understood the test, they were measured on a set of pre-identified test problems in which they were given consistent failure feedback. Following the failure experience, students were then asked to explain why they thought they had such a hard time with the preceding set. The results showed that *none* of the students identified as mastery-oriented (i.e., growth mindset) attributed their failure to lack of ability, but rather to factors such as lack of effort or task difficulty. Additionally, Diener and Dweck (1978, Study 2) found that following the failure experience, mastery-oriented children used strategies such as self-instructions (e.g., telling themselves to slow down or concentrate more), self-monitoring (e.g., monitoring their own concentration levels), positive evaluations of the challenge (e.g., "I love a challenge"), and positive prognoses of the outcomes (e.g., "I've almost got it now"), whereas the ability-oriented children were more likely to express disinterest (e.g., "This isn't fun anymore") or defeat (e.g., "I give up").

The growth mindset is not limited to children. The benefits of adopting the growth mindset carry through childhood into adulthood (see Dweck, 2006). For example, Hong, Chiu, Dweck, Lin, and Wan (1999; Study 2) studied entering university freshman in Hong Kong to assess their likelihood of taking a remedial course. They inquired about the students' scores on standardized exit exams from high school. Students who got an A or B in English—a topic required of all students—were classified as high previous performers, whereas students who did not report an A or B were classified as low previous performers in English. Researchers then asked how likely they were to take a remedial university course to improve English proficiency. Under the guise of conducting another researcher's study, students then responded to Dweck's implicit-theories measure, which consists of the following three items on a 6-Point Likert scale (1=*Strongly Agree*, 6=*Strongly Disagree*) to assess the fixed or growth mindset: 1) *You have a certain amount of intelligence and you really can't do much to change it*; 2) *Your intelligence is something about you that you can't change very much*; and 3) *You can learn new things, but you can't really change your basic intelligence*. Hong et al. found that individuals who had previously performed well expressed equal likelihood of taking the remedial course, irrespective of the mindset. However, among students who had previously performed poorly in English, those who exhibited the growth mindset were more likely than individuals with the fixed mindset to take necessary remedial action to improve their English skills. That is, students with the growth mindset were more likely to express interest in taking coursework that would benefit them, even though they had struggled with the courses in the past. Thus a preexistent growth mindset can affect adults' positive learning outcomes.

Additionally, just as children can learn to adopt a growth mindset, adult learners' perceptions of intelligence are also malleable, such that adult learners can also benefit from instruction regarding the growth mindset. Aronson, Fried, and Good (2002) researched how academic outcomes would be affected among African American university students who advocated adoption of the growth mindset to purported “at risk” middle school and college students. Over three 1-hour sessions, study participants wrote “pen pal” letters and were encouraged to advocate the belief that intelligence is malleable and changeable (i.e., the growth mindset), or to advocate that people have different kinds of intelligences in different domains, reflecting the fixed mindset. Given that public advocacy for a message increases the likelihood of adopting the message, Aronson et al. reasoned that students who advocated the growth mindset would adopt the growth mindset, and consequently would value academics more, enjoy schooling more, and show improved grades, as compared to those who did not advocate the growth mindset. As expected, nine weeks following the intervention, participants who advocated the growth mindset exceeded those who advocated the fixed mindset in terms of durable adoption of the growth mindset, enjoyment and valuing of academics, and grades as measured by transcripts. Again, the value of adopting the growth mindset is substantial and positive for both children and adults alike.

In summary, learners—both young and old—with the growth mindset retain learning motivation when challenged because they want to master the content. Their spirits become unsinkable when faced with failure. Beyond the initial failure, they persist in their learning endeavors. They do not perceive failure as threatening, but as a cue to develop more effective learning strategies, a sign that learning is taking place, and a reaffirmation that intelligence is expandable. They exhibit minimal concern regarding how others will evaluate their performance, and greater concern for mastering the subject at hand. Such attributes promote greater motivation when learning, subsequent improved learning outcomes, and content mastery.

The Fixed Mindset

The second type of belief that people may have about their own intelligence—the entity theory of intelligence, or the "fixed mindset"—portrays intelligence as hard-wired and unchangeable (Dweck, 2006, p. 213). In contrast to the growth mindset, individuals with a fixed mindset do not believe they are in control of their learning outcomes. Rather, they believe that learning a particular subject is a function of ability (i.e., either you have it or you don't), and that they do not possess the innate abilities required to succeed in the subject (e.g., "I'm not a math person"). This state, proposed and defined by Seligman as "learned helplessness," occurs when people believe they cannot do anything to change their negative outcomes, and that success depends on external, uncontrollable factors, such as inherent inability (see Dweck, 1975).

Learned helplessness is an essential component of the fixed mindset. A review of Seligman's relevant work is both informative and interesting. Seligman's (see Klinger, 1977; Seligman & Maier, 1967; Dweck & Reppucci, 1973) original studies of this phenomenon were conducted with dogs that were placed in shuttleboxes, or enclosed boxes designed with a shock plate on one side, a low barrier, and a non-shock surface on the other side of the barrier. Under normal conditions, dogs that received the shock would quickly jump about, eventually jump over the barrier, and recognize that they were no longer shocked. They learned to escape the painful outcomes of the shock by taking action and jumping over the barrier. In the experimental condition, however, the results were different. Dogs were placed in "Pavlovian Hammocks," a system of slings and straps to keep the dog in place, while the shocks were administered. Under these conditions, the dogs were unable to escape the shocks. The dogs were removed, and then placed back in the shuttlebox without the restraints, followed by the administration of shocks. Seligman found that under these conditions, the previously restrained dogs tended to stay on the shock plate, and did not try to escape the shocks. Even with the experimenter's help, the dogs were hesitant to go to the other side of the barrier.

Seligman's research showed how a helpless state could be learned. With the Pavlovian Hammocks, the dogs learned that they could not do anything that would take the pain of the shock away. Consequently, even when they had the opportunity to get away from the shocks, they behaved as if they were helpless and incapable of changing their circumstances. Seligman proposed that the dogs had learned a system of "noncontingencies," or outcomes that were not contingent upon the dogs' actions. In short, the dogs learned that they could not do anything to help themselves out of their painful situation. They learned that solutions to their outcomes were out of their control, and consequently, efforts to change their circumstance were pointless.

Following Seligman's findings with dogs, Dweck and Reppucci (1973) reasoned that "[it] is possible that children who give up in the face of failure in achievement situations are victims of a similar phenomenon: giving up may reflect their perception of independence between what they do and what happens to them" (p. 110). In these circumstances, the learner begins to attribute failure to events or circumstances that are beyond his or her control. Effort is replaced by alternative attributions or "stories" to explain the poor outcomes, with a particularly strong tendency to attribute the causes of failure to inherent inabilities (recall Viviana's "irreversible psychological pathology"), rather than effort (Diener & Dweck, 1978; Dweck, 1975). And when people believe they lack ability to succeed in a given area, motivation decreases and performance tends to steadily decline in the face of mounting evidence that they are "no good" in the particular area. Expending effort under these circumstances is perceived as a fruitless endeavor.

This preference for attributing learning outcomes to ability rather than effort is, however, not the sole impediment to motivation for individuals with the fixed mindset. The concerns and learning goals of people with a fixed mindset also contain sources of de-motivation. Whereas the belief that intelligence can grow and improve is associated with learning goals of content mastery and competence, the belief that intelligence is fixed tends to engender concerns with competence and performance evaluations. Thus the growth mindset is associated with actually *becoming* and *being* competent, whereas the fixed mindset entails concerns with *seeming* or *appearing* competent to others, or avoiding others' negative evaluations of incompetence. As Dweck and Leggett (1988) draw the distinction, the growth mindset is about *improving* competence, while the fixed mindset is about *proving* competence.

The competence concerns associated with the fixed mindset have been documented. In a study by Elliott and Dweck (1988), 5th grade children were tested to find out if different goals—to prove competence or to improve mastery—were related to the different mindsets. They first manipulated the students' perceived ability in a pattern recognition task, wherein students were asked to identify from among three cards a pattern that had been shown to the students for 2 seconds. The experimenters then randomly assigned the students (regardless of actual performance) to high or low performance groups by telling them they had either performed well or not on the task. The researchers presented each child with two boxes, and the child was instructed to choose one. For the box pertaining to performance goals (i.e., proving competence), the students were told the following: "*In this box we have problems of different levels. Some are hard, some are easier. If you pick this box, although you won't learn new things, it will really show me what kids can do*." The children were told that the performance goals box had tasks that were moderately easy, moderate, or moderately difficult. For the box pertaining to learning goals (i.e., mastering material), the students were told: "*If you pick the task in this box, you'll probably learn a lot of new things. But you'll probably make a bunch of mistakes, get a little confused, maybe feel a little dumb at times—but eventually you'll learn some useful things*." Before choosing between boxes and tasks, the students were told either that their responses would be filmed and evaluated by experts (i.e., the performance condition), or that the learning task might help them by "sharpening their minds" and improving their studies (i.e., the mastery condition). The children then chose which box and task they wanted. Irrespective of the child's choice, all children were given the same moderately difficult task following the hypothesis-generation format. To evaluate the children's thinking during the process, children were encouraged to talk out loud while they did the task. To implement a failure experience, all children were told in a series of pre-identified items that their responses were "wrong."

Results indicated that when learning was the main goal, students chose the box that would challenge them. But, when being evaluated was the primary goal, they tended to choose the less-challenging box. Their learning goals (i.e., to learn or to be evaluated positively) largely determined the challenges they would choose, with mastery goals leading to selection of more challenging material, and performance goals leading to selection of easier material. Additionally, approximately one out of every three children who were initially told they did not do well selected the moderately easy task, while *none* of them selected the moderately difficult task. Their beliefs in their abilities led these students to completely avoid the challenging task. These results provide support for the propositions that the fixed mindset is associated with performance goals as well as a tendency to avoid challenges.

Because the learning goals associated with the fixed mindset are about competence and performance, failure to look competent or perform well generally results in unproductive behaviors. This decline in learning performance has been documented as a consequence of the fixed mindset. For example, Diener and Dweck (1978) found that students with the fixed mindset had lower scores following failure with a hypothesis-generation task, showed signs of boredom (e.g., "This isn't fun anymore"), and expressed distraction from the task at hand (e.g., "There is a talent show this weekend, and I am going to be Shirley Temple"). Some ultimately chose to withdraw from learning challenges, stating "I give up."

As with the growth mindset, the fixed mindset also persists into adulthood, with its attendant negative learning outcomes. Mueller and Dweck (see Dweck et al., 1995) found that college students with the fixed mindset expressed significantly more agreement than their growth-mindset counterparts with the statements *If I knew I wasn't going to do well at a task, I probably wouldn't do it, even if I might learn a lot from it* and *Although I hate to admit it, I sometimes would rather do well in a class than learn a lot*. Fixed-mindset learners, then, are more concerned with looking competent than actually becoming competent. Consequently, they prefer tasks that help them appear competent, rather than choosing tasks that help them learn and actually develop more competencies. As another example of the negative effects of the fixed mindset extending into adulthood, Hong et al.'s (1999, Study 2) previously mentioned work with entering university freshmen in Hong Kong showed that students with a fixed mindset were less likely than students with a growth mindset to express interest in pursuing remedial English courses, even when they recognized that taking the course would be beneficial to their future and that the remedial course offered would be effective for helping them. Thus, just as adherence to the fixed mindset can be detrimental to children's learning, adherence to the fixed mindset can likewise be detrimental to adults' learning.

The conclusion that implicit theories of intelligence affect motivation in learning and are ultimately related to learning outcomes, has been well established in numerous studies (e.g., Braten & Olaussen, 1998; Dweck, 2007b, 1975; Dweck & Leggett, 1988; Elliott & Dweck, 1988). To review, students who believe that intelligence is malleable tend to have learning goals related to content mastery. As a result of these learning goals, they are more motivated and persistent in their efforts following challenges or failures. They do not see challenges or failures as threats, or even as negative, but rather as indications that learning is occurring, that content is being mastered, and that their strategies may need to be altered to achieve their learning goals. Ultimately, the growth mindset leads to improved learning outcomes. In contrast, students who believe that intelligence is fixed tend to be more concerned with how they will be evaluated by others in terms of their competence and performance. When confronted with learning challenges or failures, they attribute their struggles to a lack of ability. They also feel heightened concerns of embarrassment related to their exposed naiveté, which discourages them from pursuing challenges. In short, as compared to their growth mindset counterparts, fixed mindset learners avoid more challenges, become more distracted, bored, and disinterested when confronted with learning challenges or failures, have poorer performance outcomes, and ultimately, are more likely to respond to challenges by simply giving up.

Motivation and statistics

Because of the learning advantages of the growth mindset over the fixed mindset, the current study sought to clarify how the growth mindset can be applied to an educational computer program to motivate non-math major undergraduates to improve their statistical literacy, or the ability to evaluate statistics used in everyday multimedia formats, such as advertisements, news shows, or informational pamphlets (e.g., medical, business). In general, motivation in statistics among college students has been recognized as a top priority by researchers of statistics pedagogy, given the common perception of the "impenetrability" of this subject matter by many students (Martin, 2003; Velleman & Moore, 1996). Such aversion toward statistics is unsurprising, given that statistics have been characterized by students as “an obstacle” between them and graduation, “a painful rite of passage,” and “Sadistics” (see Gal & Ginsburg, 1994).

Not all undergraduates, however, are expected to respond to statistics with “pain.” It seems self-evident, for example, that students in math-intensive majors (e.g., finance, corporate accounting, mathematics) are likely to have a more positive evaluation of statistics, whereas students in non math-intensive majors are more likely to be the statistics-aversive students spoken of above. The latter group stands to benefit most from the growth mindset relevant to statistics, and consequently, was the focus of this study. The non-math majors predominantly considered in this research are students studying the field of communication (e.g., interpersonal, rhetorical, journalism, mass media). Given that the State of Texas requires that students complete only 3 hours of college-level mathematics to graduate (The Texas Higher Education Coordinating Board, 2007) and that the Communication Studies major requires no math courses above this minimal standard, it was expected that a large majority of Communication Studies majors would not have had extensive experience in math or statistics and would generally be averse to statistics. It was also expected that non-math majors were likely to *not* consider themselves as “math minded,” thereby identifying them as a population that could benefit from the growth mindset relevant to statistics.

Given the difficulties that some students have with statistics, research has sought to identify the factors that increase motivation to learn statistics. For example, Gal, Ginsburg, and Schau (1997) identified factors such as increasing students’ beliefs in their abilities, feeling comfortable with confusion, not being afraid to experiment, finding motivation when “muddling through” problems, identifying their beliefs about mathematics, and identifying their beliefs about their capacity to do mathematics. These factors are also consistent with the research of Budé, Van de Wiel, Imbos, Candel, Broers, and Berger (2007), who found that persistence (e.g., using textbooks, lecture notes, and asking questions to the teacher), appreciation for the challenges of statistics, and beliefs that the student is in control of the outcomes (as compared to external factors) were related to improved statistics test scores. Notably, these characteristics correspond strikingly well with the growth mindset, a correspondence which has been acknowledged (Budé et al., 2007). Because the growth mindset is a robust construct within the context of motivating college students relevant to statistics, it was proposed that the non-math major undergraduate students who participate in this study and adopt the growth mindset would show similar responses to other research that has documented the benefits of the growth mindset. This is the first hypothesis:

> H1 Feedback framed in terms of growth will promote more positive learning outcomes than unframed, direct performance feedback, as indicated by participants’ (a) decisions to choose more challenging tasks, (b) fewer “passes” on challenging items, and c) overall test performance.

Metaphors

Considering that the growth mindset holds many advantages for learners, how can instructors encourage their students to embrace it? One strategy is to couch the growth mindset in a metaphor that students find easy to understand and compelling to embrace. Instructional metaphors may be used as explanatory or motivational devices in teacher-student communication. The focus of this dissertation is on metaphor’s motivational function.

Purposes of metaphor

Explanatory metaphors. The purpose of metaphors in teaching is often to explain new information. As noted previously, Petrie (1979) proposed that metaphors are "one of the central ways of leaping the epistemological chasm between old knowledge and radically new knowledge" (p. 440). This purpose of using metaphors to explain concepts—i.e., explanatory metaphors—has been repeatedly encouraged (Brophy, 1987; Rieber & Noah, 1997; Weinstein et al., 2006; Daly & Vangelisti, 2003). The efficacy of metaphors' explanatory function has been researched in various domains, and various outcomes have been observed. For example, Rieber, Noah, and Nolan (1998) developed a computer-based simulation to evaluate the use of metaphors to explain the relationship between velocity and acceleration. While the basic simulation remained the same, the authors created experimental conditions by varying metaphorical representations of the velocity/acceleration relationship, including a ball rolling on a tilting board, a refrigerator rolling on the floor, and a space ship in outer space. The goal of the game was to change acceleration and direction of the metaphorical object, while keeping the object in a given range, as many times as possible within a period of two minutes. Following the experiment, students were asked a series of questions to evaluate their understanding of the underlying relationship between acceleration and velocity. Overall, students showed significant learning gains regarding the relationship between acceleration and velocity following the experiments, showing that metaphors were no less beneficial than explicit representations in the learning process. However, the quantitative results showed no statistical advantage for the metaphor conditions in terms of conceptual understanding.

Qualitative analyses, however, indicated that students spoke in terms of the metaphor, indicating that metaphor uptake had occurred. Also, a similar study of the effectiveness of metaphors for teaching has been conducted in relation to astronomy. Donnelly and McDaniel (1993) evaluated metaphorical descriptions of the twinkling light from a pulsar as light emitted from a lighthouse, compared to literal explanations of a pulsar. They found that students who had less previous knowledge about astronomy were able to make more inferences about pulsars when they were exposed to the metaphor condition, but were less able to recall specific details.

Specific to the context of statistics, some authors have indicated when metaphors might be particularly useful. For example, Martin (2003) has suggested increasing statistics comprehension through multiple metaphors, including comparisons of hypothesis testing to a court case, bias and variance to archery, and box plots to a leashed dog pursuing bones at varying distances, and Gordon (1995) has echoed some of this advice. However, the recommendations were not based in empirical research, and consequently, determining the efficacy of their suggestions is unverifiable. A key observation remains, nonetheless, that scholars who have studied or recommended the use of metaphors in teaching have been primarily concerned with using metaphors for the purpose of explaining novel concepts.

Motivational metaphors

Beyond their explanatory value, however, metaphors may also function as a motivational tool. The domain of motivational metaphors in learning, or the use of metaphors to specifically motivate learners in the learning process, has been heretofore unexplored. While explanatory metaphors are used to elucidate concepts that are specific to one particular subject (e.g., acceleration and velocity, astronomy, or statistics), motivational metaphors are not limited to a particular subject. Instead, motivational metaphors are concerned with the process of learning—a process that encompasses any potential subject matter. Because the link between effort and outcomes is central to the growth mindset, a metaphor that links effort (e.g., lifting weights) with outcomes (e.g., growing bigger muscles) in a learning task may encourage learners to adopt the growth mindset. That is, a metaphor that symbolically depicts the relationship between effort and outcomes may lead a student to infer that learning new material (e.g., statistics, or any other subject) is a similar process, and that outcomes in learning are related to the effort the student is willing to exert in the subject area. The focus of this research is the effectiveness of metaphors that motivate students in the learning process.

Metaphor versus literal explanation

If clarity and understanding are primary goals for teaching, why would a metaphorical description of the growth mindset be more beneficial than a literal explanation? This question is not trivial. Indeed, it is wise to consider the possibility that metaphorical explanations of concepts may be harmful to learning if misunderstood (see Donnelly & McDaniel, 1993; Ortony, 1975). If a person's knowledge of a topic is extremely limited, use of a metaphor is potentially dangerous because that person may not know the extent to which the metaphorical description accurately reflects the actual topic being discussed. Under such circumstances, the individual may fail to understand the metaphor, and may subsequently draw inferences that are incorrect. In place of learning correct material through the selected metaphor, the individual may ultimately be misled.

If a primary goal of teaching is to transfer information to learners, detailed messages that clearly explain the information would seem superior to any other strategies, and metaphors would only complicate and confuse matters. However, learning does not seem to work that way. Rather, according to Ortony (1975), learning is a process that invariably requires metaphors. In spite of their potential pitfalls in the learning process, metaphors are, in Ortony's words, "necessary and not just nice." Reflecting on the most prominent perspectives regarding metaphor in teaching, he summarized and articulated the pedagogical necessity of metaphor in an argument consisting of three theses.

Compactness thesis of metaphor. Similar to other information processing theorists (e.g., Mayer, 2005; Paivio, 1991; Sweller, 2005), Ortony proposes that life is experienced as a constant, fluid stream of input. However, the brain is limited in what it can process from the environment at any given time, and consequently, experience is de-constructed into smaller, more manageable units. One function of the brain is to "discretize" the constant stream of experience, or in other words, to break experience into meaningful bits of information that can be understood. Once discretization has occurred, learners retain separated fragments of filtered information that remove the perceived experience a few steps away from the actual experience.

When discretization has separated experience into small bits of information, Ortony suggests that individuals go through a cognitive process of reconstructing the information, or trying to put the information back together in a meaningful, coherent structure. In other words, individuals try to reconstruct a mental image of the one step-removed experience. This process of reconstruction is the process of learning. Ortony proposes that this cognitive reconstruction happens through “particularization,” or the identification of a few salient pieces of information that can then be supplemented with the “particulars” of the experience. As a simile, the process is like having a few critical pieces of a large puzzle and being able to infer what the remainder of the puzzle should look like based on the few present pieces. The critical point about particularization, as Ortony notes, is that language and large “chunks” of information can be understood without explicitly pointing out every detail, or without including every puzzle piece.

The ability to explain large “chunks” of information, based on a few, well-chosen features, is one of the functions of metaphors in the learning process. Ortony calls this the compactness function, whereby a metaphor can transmit a lot of information by highlighting a few essential characteristics, and then leaving the remainder to be filled in by the learner. The teacher, then, does not rely on explicit descriptions of every aspect of a concept, but rather may be confident that students will fill in the gaps after the most important concepts have been presented. This function of metaphor has been supported in research by Donnelly and McDaniel (1993). They compared the “twinkling” light from a pulsar to the rotating light of a lighthouse. While they found that students in the explicit conditions were able to recall a greater amount of surface, basic-level information (e.g., facts) about the science of pulsars, they found that students in the metaphorical conditions performed better on inferential questions, or questions that required more abstract comprehension. These results were particularly salient for learners who had initially less understanding of the scientific principles of pulsars. That is, while the metaphor did not improve recall of basic level information, students exposed to the metaphor condition were able to fill in the gaps and extrapolate to unstated concepts between the pulsar and lighthouse in such a way that facilitated understanding beyond the literal condition alone. The metaphor, as a compact representation of multiple relevant relationships, facilitated the (unstated) process of inference to other principles. The first reason, then, that figurative language may be preferable to explicit language when teaching is the ability of a few well-chosen attributes to transfer large amounts of information, rather than relying on explicitly detailing every particular of a concept.

Inexpressibility thesis of metaphor. A second reason Ortony proposes that metaphors are necessary in learning is the inadequacy of any language to fully express concepts, a concept which has been termed a matter of codability (McGlone, Cacciari, & Glucksberg, 1994) or inexpressibility (Ortony, 1975). While life is experienced as a constant stream of information, the discretization process relies on formal language to provide the containers into which the discrete bits of information can be placed. That is, experience is divided into bits of information, and those bits of information are then labeled or named with words (i.e., encoded) from within the learner's language. When a word fits the information precisely as intended by the instructor and understood by the student, there are no problems in teaching and learning. However, when the "perfect" word or words are unavailable to a teacher or unintelligible to a learner, communication between teacher and student is compromised. Language, then, constrains what the teacher is capable of describing and what the learner is capable of understanding.

Metaphors, however, bypass the constraints of literal language when expressing thoughts, feelings, and other aspects of experience. Given the inexpressibility that accompanies the constraints of language, concepts that cannot be adequately encoded (i.e., labeled or named) cannot be directly transferred. Instead, a large amount of un-labeled information remains that is part of the stream of experience, but is inexpressible, and therefore subject to potentially being lost. For example, trying to explain what *love* feels like is difficult, if not impossible, in literal terms. Under these circumstances of inexpressibility, speakers search for alternative means of communication. Statements such as “it is like” or “for example” are then used to convey the nameless idea. Thus, love is spoken of as a fire, or a blanket, or a flower. The inexpressible, then, is expressed through metaphors. Metaphors fill in the gaps that language cannot. In summary, speakers are forced to use metaphors because literal language cannot be used to fully express or understand the constant stream of experience. Metaphors, then, are necessary to teaching and learning because literal language is incapable of adequately (if not accurately) expressing ideas. Well-selected metaphors, then, may convey meaning which literal language cannot.

The vividness thesis of metaphor. A third reason to consider metaphors when teaching is to increase the vividness of learning, and thereby enhance overall recall and comprehension. Referring back to the process of discretization, the claim was made that discretization causes perceived experience to be one step removed from actual experience. This is so because discretization breaks down the continual stream of actual experience into smaller, cognitively manageable bits of information. In the process, some aspects of the original experience are highlighted, while others are diminished, or potentially lost. Thus, by not perceiving experience in its entirety, discretization creates a cognitive "sugar-free experience" or "experience-lite."

In contrast to the scaled-down experience associated with discretization, metaphors provide a richer, more vivid mental model which is closer to actual experience and more conducive to retention in memory. This made-in-metaphor mental model is closer to actual experience because it is not subject to the constraints of the discretization process nor is it subject to the limitations of inexpressibility. Metaphor bypasses both of these barriers to learning, or in other words, to reconstructing a mental image that most closely re-presents the actual experience. Whereas discretization may result in bits of information that cannot adequately express the experience in thoughts and feelings, metaphors are capable of transferring an entire experience, including the associated emotions, kinesthetic responses, or other attendant aspects of the original experience. Stated differently, metaphors allow recipients to reconstruct an experience that has been "swallowed whole"—complete with perceptions, cognitions, and emotions—rather than relying solely on bits and pieces of fragmented information that are limited by names and labels. Each of these elements, in turn, provides a stronger nexus of visual, textual, aural, kinesthetic, and other cognitive links that increase retention in long-term memory schema, thereby making them more memorable and more easily accessible (see Mayer, 2005; Paivio, 1991) than what literal language alone could accomplish. Thus, metaphors can create a more memorable, vivid, superior mental image of the original stream of experience because metaphors can transfer information that defies limited linguistic conventions and can also provide additional sensorial data (e.g., images, kinesthetic responses) that enhance retention in long term memory.

As an example, consider the "mind as muscle" metaphor: What are *your* experiences with strengthening muscles, and how might those relate to intelligence? By asking this fairly simple question, and comparing one's personal experience of developing muscles to intelligence, metaphor has the capacity to transfer characteristics of muscle development that don't require particular words, and that may even be difficult to enumerate and illustrate in specific words. Due to particularization and the bypass of discretization, all of these potentially unspeakable elements can be experienced through the use of the "mind as muscle" metaphor, reconstructing a more vivid mental representation of the actual experience. Short of ridiculously lengthy and precise descriptions, literal language lacks comparable vividness, and consequently, does not afford comparable memorability.

To recapitulate Ortony's arguments, then, metaphors are necessary in the learning process because they provide large amounts of information with relatively few key points (i.e., the compactness thesis), they allow teachers and learners to explain and understand ideas for which language has no particular words (i.e., the inexpressibility thesis), and they allow teachers and learners to draw on a wide array of information, and to consequently develop a more memorable mental image of what they are learning (i.e., the vividness thesis). For each of these reasons—compactness, inexpressibility, and vividness—metaphorical descriptions are likely to be superior to literal explanations when considering how to encourage learners to adopt the growth mindset.

Metaphors to bypass negative reactions

In addition to Ortony's theses regarding metaphor in teaching and learning, metaphors may also be superior to literal explanations when motivating students in the learning process due to their potential to bypass negative effects associated with imposing a particular perspective on a learner. Some negative effects have been identified when teaching about the growth mindset. First, Sternberg (1998) noted that teaching about reflecting on one's own style of thinking, as with the growth mindset, is inherently undesirable to students, particularly because it highlights that effort is necessary in order to change. Most students do not want to work hard at learning because they are accustomed to educational systems that require little effort, limited to simple learning processes of rote memory and regurgitation. Thus, the first reason students may be resistant to learning about implicit theories of learning is because it highlights effort, and effort in learning may be the very thing many students try to avoid.

A second negative effect associated with explicitly teaching about implicit theories of intelligence is that students may get the impression that they are being controlled and, in turn, may react negatively to encouragement to adopt the growth mindset. Brophy (1987) noted that if students are exposed to excessive or routine motivational learning strategies—such as explicit instruction about the growth mindset—the efficacy of those strategies may be compromised. Similarly, and specifically in regards to the use of metaphors in strategic communications, McGlone (2007) found that messages that "lay it on thick" with metaphorical terms are less persuasive and effective than those that use modest amounts of metaphorical terminologies. In consideration of the over-use of motivational strategies in teaching, it seems that students who are continually told in explicit terms to "work harder" run the risk of becoming annoyed with the dogmatism of the teacher, and may respond negatively to the well-intentioned, though misguided, motivational attempts. A potential reason for this is that students may feel the teacher is trying to force an idea on them and to control their way of thinking. According to Brehm and colleagues (Brehm, Stires, Sensenig, & Shaban, 1966; Hammock & Brehm, 1966; see also Brehm & Weinraub, 1977), feelings of being controlled may in turn engender a motivational psychological state known as psychological reactance. When people experience psychological reactance, they are motivated to restore their sense of freedom. To feel like they have their freedom back, people may use various strategies, such as rejecting the advocated message, derogating the source of the message (e.g., the instructor), or adopting a position in opposition to the advocated position, a phenomenon known as the "boomerang effect" (Miller, Lane, Deatrick, Young, & Potts, 2007). Psychological reactance may thus impede adoption of the growth mindset if students feel like they are being controlled or told they have to adopt the growth mindset.

According to Sternberg (1998), teaching about implicit theories of intelligence may inherently be aversive to students who do not want to have to put effort in to learning. Likewise, excessive efforts to motivate students may result in student perceptions of being controlled, and subsequent psychological reactance may stop students from adopting the growth mindset. The matter then becomes one of deciding how to bypass these negative effects without compromising the message itself. One strategy that has shown some promise when creating persuasive messages is the use of implicit strategies, or strategies whereby consumers of the information are less attentive to the explicit, persuasive intent of the message. For example, Grandpre, Alvaro, Burgoon, Miller, and Hall (2003) found that 10th grade students expressed fewer intentions to smoke when they were shown an anti-smoking message that did not explicitly tell them what to do, but emphasized that they could choose what they would do. Although they defined "implicit" in terms of indicating that the participants had a choice, they nonetheless showed that the explicit condition was the most likely condition to encourage psychological reactance. Thus, it appears that non-explicit messages (and therefore, implicit messages in the terminology of this dissertation) are likely to be related to less psychological reactance, and consequently, increased acceptance of the advocated message.

Because an implicit message may reduce psychological reactance, it may be inferred that if implicit metaphors are included in instruction, they may likewise reduce psychological reactance. Although metaphors can be either explicit (e.g., "Let's compare learning to a muscle") or implicit (e.g., a person's muscles get stronger when a correct answer is given), the goal of this dissertation was to specifically consider implicit metaphors, or metaphors that are not explicitly pointed out.

Based on the literature presented, metaphors serve the valuable functions of compactness, overcoming inexpressibility, and vividness. Additionally, students may be averse to learning directly about the growth mindset, such that learning will be compromised. Consequently, the following hypotheses are proposed:

> H2 Metaphorical framing of the growth mindset will promote more positive learning outcomes than no framing or literal framing, as indicated by participants' (a) decisions to choose more challenging tasks, (b) taking fewer "passes" on challenging items, and (c) overall test performance.
>
> H3 Metaphorical framing of feedback will yield less resistance to adoption of the growth mindset than literal framing, as indicated by participants' perceptions of being controlled by the computer program.

Metaphor Resonance

Given the main proposition of this research—that metaphors of the growth mindset will motivate students in the learning process—it is reasonable to consider the properties that make a metaphor motivational. What determines the degree to which a metaphor might be motivational? One important factor that may influence a metaphor's motivational potential is its "resonance," or the compatibility of a metaphor with the preferences and interests of the target audience (Ottati, Rhoads, and Graesser, 1999). For example, a metaphor that compares rock-climbing to a career is likely to resonate with a person person who is interested in rock-climbing is likely to resonate with a metaphor that compares rock-climbing to a career, and consequently would encourage the individual to remember the comparison and contemplate its implications (e.g., equating a good manager with a belayer). On the other hand, someone who is not interested in rock-climbing will be less interested by the metaphor, and subsequently will give less consideration to the advocated message.

To evaluate the influence of metaphor resonance, Ottati et al. studied the extent to which people would consider a persuasive message that contained metaphorical references to a topic that they either considered interesting or not. They found that college students who reported enjoying sports "more than the average college student" were more likely to consider a persuasive message that included references to a sports metaphor, whereas students who reported less enjoyment of sports gave the same message less consideration. They concluded that metaphors that "resonate" with a person's preferences are more interesting than those that do not, and in turn, motivation is increased to consider and evaluate the literal advocated message. In contrast, metaphors that lack resonance create boredom and inattention and result in less consideration of the advocated message. Resonance, then, may mediate how much a person will consider the literal message of a metaphor in a persuasive statement.

In consideration of the possibility that the resonance of a metaphor may mediate consideration of a persuasive message, how will metaphor resonance affect adoption of the growth mindset? That is, how will preferences for and interest in muscularity affect the consideration hearers will give to the literal message of the growth mindset? Given that this research is about the "mind as muscle" metaphor, the primary resonance that is considered is based on muscularity. However, the notion of muscularity in this research is presented as a hybrid of muscularity and physical fitness. By using the term "muscularity," I am invoking a general conceptualization of attention to muscular development. Such development may be reflected through the efforts associated with muscular development (i.e., working out) as well as a visible increase in size (i.e., getting bigger) as a consequence of working out. This distinction becomes particularly relevant when considering gendered biases toward the “bigger muscles” type of muscularity. Specifically, various studies have substantiated an increased drive for muscularity in men as compared to women, to the extent that the muscular mesomorph body shape (i.e., broad shoulders, developed chest and arms, tapered chest) has been called “the embodiment of masculinity” (Mishkind, 1986, p. 550; see also McCreary & Sasse, 2000; Pope and Olivardia, 1999). By employing a hybrid concept of muscularity that considers the process of developing muscles (i.e., working out) and the results of that process (i.e., bigger muscles), this research hopes to reduce problems of resonance that would likely be present due to gendered differences. In simple terms, males tend to want a larger muscular frame, while women tend to want a more toned muscular frame. In this research, male muscularity is represented metaphorically by a visual representation of male avatars working out and notably developing muscles (i.e., getting bigger and defined). In contrast, female muscularity is represented metaphorically by a visual representation of female avatars working out, with only slightly noticeable changes to their muscular development. While the avatars’ body shapes will change according to the male or female representation of muscularity, the activities in both conditions will be identical (e.g., the exercises, holding weights).

Due to the distinction between male and female muscularity, and in consideration of resonance, it is likely that an individual who is interested in muscle development/fitness will like and be interested in the “mind as muscle” metaphor. This interest, in turn, will encourage the person to consider the literal message of the metaphor (i.e., the growth mindset) and increase the likelihood of adopting the advocated message. In contrast, a person who is not interested in muscle development is unlikely to be interested in the muscle metaphor, and consequently, may be less motivated to consider and embrace the message being advocated. Thus, it is proposed that individuals who prefer and are interested in muscle development via working out are more likely to be interested in and respond to the "mind as muscle" metaphor than individuals who are less interested. Metaphor resonance, then, may mediate the outcomes between exposure to the motivational metaphor and the learning outcomes, as reflected in the following hypotheses:

> H4 Participants who report *a high degree* of interest in muscle development will exhibit positive learning outcomes when exposed to a growth mindset message that metaphorically equates topic mastery with muscle development. These outcomes will include (a) decisions to choose more challenging tasks, (b) fewer "passes" on challenging items, and (c) overall test performance.

> H5 Participants who report *a low degree of* interest in muscle development will not exhibit positive learning outcomes when exposed to a growth mindset message that metaphorically equates mastery learning with muscle development.

As noted previously, it is likely that muscularity will resonate differently with participants, according to gender. Also, it was noted that male muscularity will depict visible changes in the size of the male avatars' muscles. In spite of attempts to equalize representations of muscularity, the concept of the "mind as muscle" may inherently carry more interest to males than females, and may consequently be more effective for male participants than female participants. Various studies have substantiated an increased drive for muscularity in men as compared to women. For example, McCreary and Sasse (2000) asked male and female participants between the ages of 16 and 24 to respond to the *Drive for Muscularity Scale*¸ which includes items such as *I wish that I were more muscular, I think that my arms are not muscular enough,* and *I lift weights to build up muscle.* Their results indicated that males were significantly more likely than females to be concerned with muscularity and muscle development. These findings are supported by the work of Pope and Olivardia (1999) that assessed portrayals of masculinity in action figures over time. They measured the circumferences of the biceps, chest, and waist of early GI Joe (beginning in1964) and Star Wars (beginning in 1978) action toys, as compared to the same line of figures through the mid-1990's. They found that more modern male action figures are consistently more muscular than their predecessors. While Pope and Olivardia caution against making causal statements about their findings (i.e., that children's toys *cause* increased expectations for muscularity), they nonetheless suggest that the findings are reflective of a social identity of male muscularity. Given these findings, it is expected that metaphors of muscularity will resonate more with male participants than with female participants, and consequently, that males in the "mind as muscle" metaphor condition will show improved outcomes in learning as compared to women in the same condition.

H6 Male participants exposed to the "mind as muscle" metaphor will have more positive learning outcomes than female participants in the same condition.

Metaphors to bypass resistance

A final factor that merits consideration is the impact of using metaphors as a teaching strategy. Previously, it was noted that explicit teaching about the growth mindset may create resistance to its adoption. As noted, Sternberg (1999) claimed that students resist learning about the growth mindset because it emphasizes effort and they are accustomed to educational systems that do not require much effort. Additionally, Brophy (1987) cautioned about excessive use of motivational strategies. If students become annoyed with the dogmatism of the teacher, they may respond negatively (i.e., with psychological reactance) to the well-intentioned, though misguided, motivational attempts (Brehm et al., 1966). These negative responses to control attempts—devaluing the teacher, engaging in behaviors opposite those advocated, and others—associated with explicit instruction of the growth mindset may lead learners to ultimately resist and forego adoption of the growth mindset.

Metaphors, however, may sidestep these concerns. Specifically, metaphors of growth may bypass students' perceptions of having to exert effort and feeling bothered by the teacher's motivational attempts because they do not explicitly tell learners "You need to study harder if you want to do well." Rather, the growth metaphors simply imply the cause and effect relationship of the growth mindset. By implicitly integrating the effort-outcomes relationship as feedback, students are not being explicitly told they have to work harder, thereby bypassing the potential negative effects associated with explicit directives. This research, then, evaluated the effectiveness of metaphors to bypass resistance to adopting the growth mindset.

> H7 High reactance participants will exhibit more positive learning outcomes when exposed to a metaphorical growth mindset message than a comparable literal message.

> H8 Low reactance participants will exhibit comparable positive learning outcomes when exposed to metaphorical or literal growth mindset messages.

As a final note, it is important to recognize that study participants entered this experiment with an a priori mindset somewhere on the continuum between an extreme fixed mindset and an extreme growth mindset. To account for these differences, responses to Dweck's implicit-theories items (see Hong et al., 1999 for a thorough rationale of the three-item measure) are treated as a covariate in analyses of participants' learning outcomes. Dweck and her colleagues have typically used scores on this measure to divide their samples into fixed- and growth-mindset learners via median split. However, this strategy has come under fire recently for a variety of reasons, chief among them being the dubious rationale for dichotomizing a sample on the basis of an ostensibly continuous predictor variable (MacCallum, Zhang, Preacher, & Rucker, 2002). This project instead treated the mindset measure as a covariate in the analyses of learning outcomes, which allowed a more comprehensive picture of how participants responded along the entire continuum. An additional reason to use mindsets as co-variates is to standardize any differences that may be associated with gender and mindsets. Dweck (1986) has noted that, on the whole, girls are more likely than boys to have a fixed mindset. And, as a correlate, boys are more likely to have a growth mindset. These differences seem to be salient during junior high school, and extend well into adulthood. Thus, by co-varying scores based on gender, the results will more clearly be able to identify the role of the framing conditions, rather than any confounds that might result from gender differences in the mindsets.

CHAPTER 3: METHODS

Participants

Students enrolled in undergraduate communication studies courses were recruited to participate in the study in exchange for extra credit. The goal was to recruit non-math oriented students, but some students in math intensive majors (e.g., business finance, mathematics) also participated by virtue of their enrollment in the communication courses. The total sample consisted of 158 students. Because this study focused on non-math majors, 26 participants identified as majors in math intensive subjects were removed from the data set, leaving a total $N = 132$, consisting of 42, 46, and 44 participants in the Control, Literal, and Metaphor framing conditions, respectively. Males and females were equally distributed across the framing conditions to balance the representation of gender in each condition. Although not asked specifically, the approximate age of the students is expected to be between 18 and 24, with an average age of 20.6, based on demographics of undergraduate college students at the University of Texas at Austin (The University of Texas at Austin, Office of Information Management and Analysis, 2009, p. 11).

Design and Procedure

This experiment used a 2 x 3 factorial design with participant gender (male, female) and mindset framing condition (control, explicit literal, and implicit metaphorical) as between-participants factors. Early in the Spring semester, students in communication studies courses were recruited for "a study about how students develop critical thinking skills." The reason for not indicating the specific purpose of the study was to avoid deterring participation of students who may stand the most to benefit from participation, namely, those students who have an aversion to math or statistics.

Upon arriving to the lab, students filled out the appropriate consent form, and were then seated at a table with a computer. The table was in the corner of a room, with an additional partition on the open side, such that the participants were isolated throughout their participation. After completing the appropriate consent forms, they were instructed to read a one-page introduction to the experiment, indicating that the study was about critical thinking, particularly as it related to statistical literacy. The written material also introduced them to the instructions for using the computer program, in addition to directing them where to look for written feedback to their answers. When they finished reading, they notified the researcher, and were then told by the researcher that they could begin the computer program.

Four versions (see below) of the computer program—each corresponding to aframing condition—consisted of the same basic format. Each program consisted of three phases. In preparation for the three phrases, a pilot study using Schield's (2008) Statistical Literacy Survey V2 (W. M. Keck Statistical Literacy Project, personal communication, December 15, 2008), was conducted with an independent sample. All the items in the survey are multiple-choice questions, and include items such as "*If Jay is older than Tom and Nan is younger than Jay, than Nan must be older than Tom,*" "*For any group of adults, the 'percentage of adult smokers who are female' is ALWAYS more than 'the percentage of adults who are female smokers*'" and "*Last year's budget was $4 million; this year it's $4.4 million. How does this year compare with last year as a* *percentage change? Pick the closest.*" The Statistical Literacy survey was used specifically because of the assumption that, given enough effort, basic logic and a basic understanding of math were sufficient to respond to the items. That is, participants could potentially answer each item correctly given enough effort to consider the items carefully. Had another measure been used, such as having students complete a T-Test, or identifying Standard Deviations, for example, a specific skill set would have been required, and previous knowledge would have been more of a determining factor in performance than effort alone. Thirty-four students in a communication studies course responded to the survey's original 45 items. Based on the number of items answered correctly by participants, responses were divided into three levels: easy, difficult, and moderately difficult. Six items were selected from each level for the final items, for a total of 18 testing items (see Appendix A for a complete list of items used). Easy items were those that were correctly answered by 85-100% of participants. Difficult items were those that were correctly answered by 0-20% of participants. And moderately difficult items were those that were responded to correctly by 45-55% of respondents.

The tri-partite division—easy, difficult, and moderately difficult—was made for the express purpose of meeting the needs of the research. Presentation of the tri-partite division was standardized across all framing conditions. The use of extreme scores for the easy and difficult items was necessary for the experimental design. Specifically, the easy items were used in the first phase, and were necessary to allow participants to answer items correctly and see the feedback they would receive. Had they begun with more difficult items, they may not have answered them correctly, and would not have had experience familiarizing themselves with the feedback mechanisms of the computer program. The difficult items, used in the second phase, had to be of sufficient difficulty that participants could reasonably believe they answered incorrectly. This phase involved a planned failure experience (detailed below), wherein participants were told their responses to the final four items in the phase were incorrect, regardless of their actual answer. If the answers were easy, and participants were highly certain the answer they provided was correct, participants could begin to question the legitimacy of the program, thereby compromising its efficacy. Finally, the third phase consisted of the moderately difficult items. The moderately difficult items were selected from those between 45% and 55% because this range provided the greatest range of variability in assessing improvement or declines in performance. Under these circumstances, participants could potentially show a 0-55% improvement (e.g., from 45% to 100%), or a 0-55% decline (e.g., from 55% to 0%). Selecting easier (e.g., 70-80%) or more difficult items (e.g., 30-40%) would not have allowed the same range of variability. For example, while selecting items from the range of 70-80% could potentially demonstrate up to 80% in performance decrease (i.e., from 80% to 0%), it could only demonstrate up to a 30% increase (i.e., from 70% to 100%). Selecting items from a 30-40% range would result in a similar trend, with the exception that it would be in the opposite direction, potentially demonstrating large gains in learning, but not adequately addressing large decrements. Based on this rationale, the mid-range of 45%-55% seemed most appropriate for measuring variability in performance.

Throughout the course of the three phases, the dependent variables of interest were integrated into the computer program. The dependent variables of interest, based on previous research about the growth mindset, were 1) tenacity when confronted with learning challenges, 2) selecting challenging tasks, and 3) performance following a failure experience. To measure tenacity in learning challenges, each item had a "Pass" option as an answer. That is, participants were able to simply indicate a "Pass" on any testing item and proceed to the next question. When the "Pass" option was selected, negative feedback was given, just as if they had actually selected a wrong answer. Fewer decisions to "Pass" on items were used to indicate greater tenacity in learning, and consequently, greater presence of the growth mindset.

The second dependent variable, acceptance of challenging tasks, was measured following each phase. After finishing each phase, and following the example of Elliott and Dweck (1988), participants were asked to choose whether they would like the next phase to be "easy, moderately difficult, or difficult." Irrespective of their choice, however, all participants received the same difficulty of items—easy, difficult, moderately difficult—in each of the three phases, respectively. The overall number of times (out of three) participants chose the moderately difficult or difficult task was used to indicate presence of the growth mindset, while choosing the easy task indicated that participants were not adopting the growth mindset.

The final dependent variable was overall test performance, as measured by summing the total number of items answered correctly in all three phases. Initially, plans were considered to measure the number of items answered in the third phase only. The rationale for this was to assess how participants would respond following a failure experience. However, the decision was made to use overall performance scores, given that participants were being exposed to the different mindset messages throughout the experiment. Consequently, performance in each phase could potentially be influenced by the framing condition. Additionally, evaluating performance on 18 items (from all three phases) as compared to 6 items (from the third phase only) would provide greater granularity for measuring any changes between conditions. In light of these considerations, overall test performance scores were analyzed as a dependent measure.

To finish the computer program, after the third phase was completed, participants again selected the level of difficulty they wanted for the next phase. After making their selection, however, participants were then told on the computer screen that they had done a good job, that they displayed adequate statistical literacy, and that no further questions were necessary. They were then instructed to press a button labeled “Next,” where they were transferred out of the computer program to a website to complete a series of survey items comprised of measures (see Measures) relevant to the research.

Mindset Framing Conditions

As noted above, the procedure for each framing condition was standardized, in that all participants followed the same research process, and were exposed to the same format of phases (i.e., easy to difficult to moderately difficult), and the same testing items within those phases. While the pattern of testing phases remained consistent, however, the conditions varied in terms of the content that was presented in conjunction with the testing portions of each phase. These experimental variations are now presented in detail.

The *control condition* involved participants completing the three phases of the study with no literal or metaphorical reference to the growth mindset. A welcome screen introduced the program with the title "Testing Module: Statistical Literacy." Instructions were given on the screen to press an "Enter" button to begin. A screen introducing "Phase 1" then told them to click the "Next" button when they were ready to begin. The test appeared in the center of the screen, composed of the question, check boxes with corresponding answers, and provisions for participants to answer via the computer (e.g., clicking on the correct response). Figure 1 presents the computer interface for the testing portion of the control condition. Feedback in the control condition consisted of a response box that indicated the participant's answer was "Correct" or "Incorrect." After responding to each item and receiving feedback, participants then proceeded to the next item. Phases 2 and 3 were presented similarly. In summary, the control condition simply involved responding to the items, with immediate feedback on their performance.

The *Explicit Literal condition* involved participants completing all testing phases as indicated in the Control condition, with the addition of literal representations of the growth mindset in text and images. The initial welcome screen was titled, "The Learner's Effort: Statistical Literacy," and included an accompanying image of a gender-neutral figure (i.e., a wooden posing mannequin) in a thinking pose. Upon proceeding into the program further, the screen was divided into three parts: an image window (bottom left), a progress bar (top full), and the testing window (bottom right). The literal representation of the growth mindset was depicted by again showing the gender-neutral figure appearing to work on some difficult problems in the image window (e.g., chin on the fist), along with a graphical representation of incrementalism, or improvement through progressive stages. In each testing phase, participants received and provided answers to questions in the same format and presentation as in the control condition. And, as in the control condition, participants received feedback to their responses. However, in the literal condition, the feedback was different in that the text that was used when participants answered incorrectly reflected the growth mindset, and a faded bar graph at the top of the screen visually indicated incremental progress (see Figure 2). When participants answered an item correctly, they received the feedback phrase “Yes. That is correct,” and the faded visual bar graph brightened by one unit (with the entire graph consisting of six distinct units corresponding to each of the six questions), from the left of the screen to the right of the screen, with each correct answer. When participants answered incorrectly, negative feedback consisted of phrases that presented the growth mindset in literal terms (e.g., “Nope! Work harder!,” “Nope. Keep trying,” or “Incorrect. Don’t give up now!”). When items were answered incorrectly, no change occurred in the bar graph. In short, visual and textual components accompanied the feedback in the explicit literal condition.

The *“Mind as Muscle” metaphor conditions*, similar to the Explicit Literal condition, consisted of graphical and textual feedback on the computer monitor as performance feedback. Two versions—a male and a female version—were created to be used according to participants’ respective gender. The graphical feedback was created using Poser 3-D modeling software (e-frontier, 2006), which allows designers to model and animate 3D humans and other figures in a wide range of bodily variations, including animations of the gradual morphing from one body type (e.g., a slight build) to another (e.g., a mesomorphic, or muscular build), along with some standardized animated behaviors from TrueBones (McPeak, retrieved 2008) and Anakele Vision and Design (retrieved 2008).

As in the other conditions, items were presented on the computer monitor and participants entered their answers using the computer mouse. The welcome screen was titled, “The MindGym: Statistical Literacy,” and was accompanied with a logo of an oversized brain placed on a weightlifting bench. After this initial screen, similar to the Explicit Literal condition, the screen was divided into three parts: the avatar’s workout window (bottom left), the avatar’s progress bar (top full), and the testing window (bottom right). The avatar’s workout window showed an image of an avatar (male or female, dependent on the participant’s gender) in workout clothing. Figure 3 shows the computer interface for testing portion of the female and male metaphor conditions. When participants answered a question correctly in the testing window, a clip of the avatar working out was played for approximately 2 seconds (in the bottom left window). As participants responded correctly over the course of the six questions in each phase, the avatar continued the workout and became more muscular. Muscular development was very pronounced in the male condition, while it was much more subtle in the female condition. The workout scenarios were the same in both the male and female conditions, beginning with a Caucasian avatar working out with dumbbells in the first phrase, an African American avatar doing push-ups in the second phase, and a different Caucasian avatar doing sit-ups in the third phase. With this design, each clip metaphorically represented the growth mindset by showing effort (i.e., working out) and growth outcomes (i.e., increased muscularity).

In addition to the workout window, the third window of the screen (across the top) also represented the avatar's overall progress in the testing phase, but in a more linear, incremental "point A to point B" fashion, similar to the representation in the literal growth mindset condition. Unlike the literal condition, however, on the left hand side of the window was the faded image of the beginning average-body shape of the avatar, and on right hand side was the faded image of the ending muscular body shape, with four similar images in transition between the beginning and ending images. As items were answered correctly, each avatar image was successively highlighted. Thus, the six images showed incremental muscle development, corresponding to each of the items answered correctly. As in the Explicit Literal condition, presence of the faded images was believed to cue the participants to what the avatar could become, and consequently, lead participants to look for the gradual changes in body shape as they worked toward the ending body shape. As with the video clips, the male avatar in the progress bar showed significant growth in muscularity, while in the female condition the avatar showed only slight alterations in muscular development.

Thus, when participants answered items correctly, they received positive textual feedback ("Yes. That is correct") and visual feedback in the form of seeing the avatar work-out and one image brightening on the progress bar. However, when participants in the metaphorical condition answered an item incorrectly, no change happened in the avatar (i.e., the next clip did not play) or the avatar progress window. When items were answered incorrectly, participants were given feedback that indicated that they did not get the correct answer, including items such as “You’ll have to sweat harder than that,” “Don’t let your mind get flabby,” and “No pain, No gain.” The feedback on each item corresponded to the feedback on each item in the literal condition, such that the same underlying messages were given as feedback on the same questions, but metaphorical statements were used rather than the literal statements (e.g., “Come on. Give it more effort!” and “Come on. Make it burn!”).

Measures

When research subjects finished the three phases of testing, they then selected a button on the computer program that transferred them to an online survey (i.e., Qualtrics) where they responded to a series of measures that addressed the hypotheses tested in this research. Each of these measures is now presented in the order of their administration. A complete set of the measures is available in Appendix B.

Implicit Theories of Intelligence

Assessing implicit theories of intelligence was conducted by asking participants to respond to three items on a 6-Point Likert scale (1=*Strongly Disagree*, 6=*Strongly Agree*): 1) *You have a certain amount of intelligence and you really can't do much to change it*; 2) *Your intelligence is something about you that you can't change very much*; and 3) *You can learn new things, but you can't really change your basic intelligence*. Dweck’s initial items place “1” as Strong Agreement, and “6” as Strong Disagreement. In this research, however, the scale was reversed to maintain consistency among all of the measures, thereby reducing the likelihood that participants may respond incorrectly due to changing the scale properties between measures. Responses were combined to form a single mindset measure. Higher scores indicated greater adherence to the fixed mindset, while lower scores indicated greater adherence to the growth mindset. This scale demonstrated strong internal consistency ($\alpha = .91$).

For data analysis, the mindset measure was used as a covariate in order to account for more precise differences in adherence to the fixed or growth mindsets across a continuum. Although Dweck and her colleagues have used a median-split to identify two distinct groups of "Growth Mindset" or "Fixed Mindset" individuals (see Hong et al., 1999), the median-split results in larger categories with less precise information about the distinctions both within and between categories (upon which tests of variance/ significance are based), which may in turn misrepresent and skew the actual results (see MacCallum et al., 2002). Regarding the use of only three items to assess implicit theories of intelligence, Hong et al. (1999) provided a thorough review of the rationale and research that has been conducted to confirm the validity of the three-item measure (see also Braten & Olausen, 1998; Dweck, 2007b).

External Control Perceptions

Given that perceptions of control are likely related to reactance (i.e., higher perceptions of control may lead to higher reactance), and that reactance may be related to adoption of the growth mindset (i.e., higher reactance may lead to less adoption of the growth mindset), accounting for control perceptions was critical for this study. To evaluate the extent to which participants believed the framing conditions were attempting to control them, a series of questions were asked based on the example of Grandpre, Alvaro, Burgoon, Miller, and Hall (2003). Four 5-point Likert scales ranging from 5 (*strongly agree*) to 1 (*strongly disagree*) formed the measure of control perceptions, including *The computer program was trying to control how I answered the questions, The computer program was trying to control what I thought, The computer program tried to make me work too hard,* and *The computer program tried too hard to motivate me.* Support for the hypothesis that metaphors may bypass perceptions of control would be achieved if participants in the metaphorical conditions had significantly lower scores on the measure of control perceptions than participants in the control and literal conditions. Reliability of the control perceptions measure was fair (α = .73).

Hong Psychological Reactance Scale

Participants' psychological reactance was assessed using the Hong Psychological Reactance Scale developed by Hong and Page (1989; also see Dowd, Milne, & Wise, 1991; Thomas, Donnel, & Buboltz, 2001). Participants responded to 11 different statements using 5-point Likert-type response scales (1 = *disagree completely*, 5 = *agree completely*). Examples of included items are *I resent authority figures who try to tell me what to do, If I am told what to do, I often do the opposite,* and *I resist the attempts of others to influence me.* The 11 questions were summed into a single measure of reactance, providing good internal consistency (α = .83). The HPRS measure was used to evaluate the effectiveness of metaphors for bypassing resistance to learning. Participants in the metaphorical framing conditions with high scores on the HPRS, but low scores on External Control Perceptions (see previous) and high scores on learning outcomes would confirm the effectiveness of metaphors for bypassing resistance. Participants in the literal condition with high HPRS who have high External Control Perceptions scores, and low scores on learning outcomes, would confirm the aversion that some students experience toward explicit teaching attempts.

General Fitness and Muscularity

In order to evaluate resonance of the muscularity conditions, it was necessary to assess general attitudes toward muscularity and fitness. Fitness items were presented first, followed by the muscularity items. Six items were used to assess general fitness. Five of the items were scored on a 7-Point Likert Scale (*-3 = Strongly Disagree*, *3 = Strongly Agree*), and requested participants to respond to items such as “Presently, I am in excellent physical shape,” “When I exercise, I usually have as much energy and stamina as I need,” and “Physical fitness is an extremely high priority for me in my life right now.” The final question focused on behaviors, asking participants to indicate “On average, how many days per week do you workout?” All items were compiled into one measure, which demonstrated strong reliability ($\alpha = .91$). It was expected that those who scored higher on these items would resonate more with the metaphorical conditions than those who scored lower on these items.

To control for muscularity as a potential nuisance variable, four items selected from Markland and Hardy’s (1993) Exercise Motivations Inventory were included to assess participants’ interest in muscular development, particularly as it related to a more male-dominated perspective of muscularity. The items were scored on a 7-Point Likert Scale (*-3 = Strongly Disagree*, *3 = Strongly Agree*), and requested participants to respond to the following reasons they exercise (or might exercise): “to achieve greater muscle mass," "to become strong and powerful," "to tone and define my muscles," and "to increase my body size." All items formed one measure (α = .80), with a higher score indicating greater interest in muscularity, and a lower score indicating less interest in muscularity.

Attitudes Toward Statistics

Based on Wise's (1985) Attitudes Toward Statistics Scale, seven items were selected to assess participants' beliefs and attitudes toward statistics and to evaluate how the research population (i.e., undergraduate non-math majors) perceives statistics. The items were scored on a 7-Point Likert Scale (-*3 = Strongly Disagree*, *3 = Strongly Agree*), and included items such as "*The thought of being enrolled in a statistics course makes me nervous*," "*Studying statistics is a waste of my time*," and "*I am excited about the possibility of actually using statistics in my job*." This scale verified good internal consistency (α = .84). Lower scores on the Attitudes Toward Statistics items would indicate that the sample population tends to be aversive to statistics learning, and consequently, are more likely to hold the fixed mindset relevant to learning statistics, whereas higher scores would disconfirm such aversion.

General demographics

The demographics of interest were gender, educational status (i.e., year in school), and educational major(s). Participants were also asked about their performance in previous math courses, as well as how many college-level math courses they have taken.

After all materials were completed, participants were debriefed through the online survey, thanked, and dismissed.

CHAPTER 4: RESULTS

Framing condition, gender, and learning outcomes (challenges, passes, total scores)

Framing condition and learning outcomes

H1 proposed that feedback framed in terms of growth would promote more positive learning outcomes (i.e., choosing more challenging tasks, passing on fewer items, and overall test performance) than unframed, direct performance feedback. H2 proposed that metaphorical framing of the growth mindset would promote more positive learning outcomes than literal framing. In addition, H6 proposed that male participants exposed to the “mind as muscle” metaphor would have greater learning outcomes than female participants in the same condition. These three hypotheses were first tested by conducting a 2 X 3 factorial multivariate analysis of covariance (MANCOVA), with gender and framing condition as the independent variables and acceptance of challenging tasks, number of overall passes, and total test score as dependent variables. Implicit theories of intelligence, attitudes toward statistics, muscularity interest, fitness interest, and reactance were entered as covariates.

The omnibus test revealed significant main effects of framing, $F(6, 220) = 3.80$, $p < .01$, partial $\eta^2 = .091$, and gender, $F(3, 110) = 8.15$, $p < .001$, partial $\eta^2 = .182$. There was also a reliable gender X framing interaction, $F(6,220) = 2.72$, $p < .05$, partial $\eta^2 = .069$. Implicit theory, reactance, fitness, and muscularity were not significant covariates; however, total attitude toward statistics was significant, $F(3, 110) = 8.15$, $p < .001$, partial $\eta^2 = .182$. The univariate analyses for each dependent variable were examined and used to compute planned comparisons testing the specific predictions of each research hypothesis. Examination of the univariate tests indicated potential partial support for H1 and H2. A main effect of framing condition was obtained for the dependent variables acceptance of challenge, $F(2, 122) = 5.68$, $p < .01$, and overall score $F(2, 122) = 5.97$, $p < .01$, but not for number of passes, $F(2, 122) = 1.06$. There were also significant main effects of gender on acceptance of challenge, $F(1, 122) = 7.55$, $p < .01$, number of passes, $F(1, 122) = 6.75$, $p < .05$, and total score, $F(1,122) = 14.36$, $p < .001$.

Consistent with H1c, a planned comparison indicated that participants exposed to the growth mindset through the metaphor (M=10.67, SD = 2.29) or literal framing (M=9.55, SD = 2.15) conditions earned scores that were marginally higher than those of participants in the control condition (M = 9.18, SD = 2.42), $F(1, 112) = 3.50$, $p < .06$ but did not vary significantly in acceptance of challenges (H1a) or number of passes (H1b). These results indicate that framing feedback in terms of the growth mindset resulted in better scores than the no frame condition, but did not significantly affect learners' acceptance of challenges or passes on difficult items.

Support for H2a and H2c was indicated by those in the growth metaphor framing condition (M = 5.63, SD =1.68) accepting more challenges than those in the literal (M = 4.70, SD = 1.43) or control (M = 4.83, SD =1.39) conditions, $F(1, 112) = 4.94$, $p < .05$, and having higher overall scores (M = 10.67, SD = 2.29) than participants exposed to the literal growth frame (M = 9.55, SD = 2.15) or the control condition (M = 9.18, SD = 2.42), $F(1, 112) = 4.94$, $p < .05$. The number of passes did not vary (H2b). These results are reported in Table 1. The outcomes suggest that learners accepted more challenges and scored better overall when they were given feedback in the metaphorical "mind as a muscle" form, as compared to receiving literal growth feedback or feedback with no reference to the growth mindset.

Gender and learning outcomes

H6 predicted that males exposed to the "mind as muscle" metaphor condition would accept more learning challenges, have fewer passes, and have higher overall scores than females in the same condition. As indicated in the aforementioned MANCOVA, a significant gender X framing condition interaction was observed. To test H6, the responses of male and female participants in the metaphor condition were analyzed in an analysis of co-variance (ANCOVA), with gender as the independent variable, and acceptance of challenges, number of passes, and overall score as the independent variables. Implicit theory, reactance, fitness, muscularity, and total statistical attitude were entered as covariates. Consistent with H6c, a main effect for gender was present, with males (M = 11.95, SD = 1.76) scoring higher overall than females (M = 9.53, SD = 2.14) in the metaphor condition, $F(1,38) = 10.36$, $p < .01$, partial $\eta^2 = .245$. However, no main effects were found for acceptance of challenges (H6a) or number of passed items (H6b). Table 2 shows mean scores and standard deviations by gender in each framing condition. These results indicate that males had better overall scores than females when they received "mind as muscle" feedback, but that acceptance of challenges or number of passes did not vary significantly by gender, whether exposed to the control, literal, or metaphor frames.

Framing condition, control perceptions, and reactance

H3 proposed that metaphorical framing of feedback would yield less resistance to adoption of the growth mindset than literal framing. However, H3 was not supported; a 2 (Gender) X 3 (Framing Condition) factorial analysis of variance (ANOVA) with control perceptions as the sole dependent variable did not reveal any significant main effects of gender, framing condition, or the interaction on control perceptions, $p > .10$ in all cases. That is, resistance to the growth mindset—as measured by perceptions of being controlled—did not vary significantly between framing conditions. Participation in the control, literal, or metaphor framing conditions did not feel more or less controlled in any one of the frames over another. Given that the ANOVA did not yield any significant main effects or interactions, no further analyses were conducted regarding control perceptions.

H7 and H8 were evaluated by performing a median split ($Md = 65.0$) on the total scores from the Hong Psychological Reactance Scale to create High and Low trait reactance groups. A 2 (High/Low Reactance) X 3 (Framing Condition) factorial multivariate analysis of co-variance (MANCOVA) was conducted, using acceptance of challenges, number of passed items, and overall scores as dependent variables. Implicit theory, fitness, muscularity, and total statistical attitude were entered as covariates. H7 and H8 were not supported, in that no main effects were found for reactance level on challenge acceptance, number of passes, or overall scores or the reactance level X framing condition interaction, $p > .10$ in all cases. That is, being in the low or high reactance category did not appear to influence acceptance of challenges, number of passes, or overall scores in any given framing condition over another. Consequently, no further analyses were conducted.

Framing condition, muscularity/fitness interest, and learning outcomes

Hypotheses 4 and 5 were tested via mediation analysis, following the guidelines of Baron and Kenny (1986). H4 proposed that participants who report *a high degree* of interest in muscle development would exhibit positive learning outcomes when exposed to a growth mindset message that metaphorically equates topic mastery with muscle development. H5 proposed that participants who report *a low degree of* interest in muscle development would not exhibit positive learning outcomes when exposed to a growth mindset message that metaphorically equates mastery learning with muscle development. A primary requirement that must be met prior to conducting mediational analysis is that the independent variable (e.g., framing condition) must significantly predict the mediating variable (e.g., muscularity/fitness interest). Self-reported scores on both the Muscularity and Fitness items were considered, independently, as the mediating variable between the metaphor condition and learning outcomes. H4 and H5 were not supported; beta weights in the regression analyses did not indicate a significant predictive relationship between the framing condition and scores on the muscularity ($\beta = .204$, $p = .74$) or fitness items ($\beta = 1.454$, $p = .08$). Consequently, the first requirement for mediational analysis was not met, and no further analyses were necessary, as no mediating effect will be found. Interest in muscularity or fitness did not change the learning outcomes achieved in any of the framing conditions.

CHAPTER 5: DISCUSSION

The question of how to encourage unmotivated students has attracted the attention of researchers and instructors who want to provide the best possible opportunities for learning. When confronted with students who seem unmotivated, some instructors may ask whether the lack of motivation is due to a lack of ability rather than a lack of effort. One learning domain where these questions are particularly salient is statistics education. Dweck's exploration of implicit theories of intelligence is at the forefront of scholarship that contemplates the effect of learners' beliefs about their own intellectual capabilities, and the subsequent consequences of those beliefs in terms of motivation, persistence, and learning outcomes. Specifically, her work demonstrates the importance of recognizing that intelligence is a function of effort: students can achieve mastery of any subject—statistics included—if they conceive their intelligence as malleable (i.e., the growth mindset). Considered in its totality, Dweck and others who have advanced this idea have offered a theoretical package that makes a compelling claim regarding student motivation and learning and applies well to the task of motivating students of statistics.

Beyond the basic theory one component that has not heretofore been considered is the role metaphor can play in encouraging adoption of the incremental theory of intelligence. Specifically, Dweck has shown that literal feedback regarding the growth mindset—telling students explicitly that they can develop their intelligence through concerted effort—results in greater acceptance of learning challenges, more tenacity in the face of intellectual challenge, and improved overall learning outcomes (see Diener & Dweck, 1978; Dweck, 1975). However, the multifaceted benefits of the growth mindset are succinctly and compellingly conveyed by the "mind is a muscle" metaphor. The purpose of this study was to evaluate the effectiveness of representing effort and encoding performance feedback in terms of this metaphor to encourage the growth mindset.

Several findings of the reported research shed light on metaphor's utility in promoting the growth mindset. First, it has shown that feedback mechanisms in a computer tutorial are capable of implicitly and successfully framing a learning experience in terms of the growth mindset. The particular mechanisms of the computer program presented feedback that made no reference to the growth mindset, or emphasized the growth mindset in literal terms or metaphorical terms through graphical and textual representations of growth (e.g., progress indicators; an avatar working out; encouragements to work harder). Given that previous research had established the benefits of adopting the growth mindset, it was believed that the same benefits could be transferred symbolically through graphics and text to learners. While exposure to the growth mindset frame (literally or metaphorically) did not result in participants accepting more challenging learning tasks or passing on fewer difficult items, exposure did result in higher overall performance scores than the scores of those in the control condition. This finding suggests that encouraging the growth mindset—either literally or metaphorically—through performance feedback can measurably improve an individual's learning performance.

Second, and perhaps most central to this study, it was found that using the "mind as muscle" metaphor as feedback was more effective than literal growth-oriented feedback or neutral feedback, in terms of helping students to accept more learning challenges and to improve overall testing performance. When compared to the aforementioned results of presenting the growth mindset in literal *or* metaphorical terms, it appears that the metaphorical frame results in additional learning gains. Specifically, presentation of the growth mindset in literal *or* metaphorical terms improved overall scores, compared to no mention of the growth mindset. However, when the metaphor presentation was considered independently in comparison to the literal or control conditions, overall scores were improved *and* participants accepted more learning challenges. Thus, these findings suggest that integration of the growth mindset as feedback will provide *good* learning outcomes, but integration of the growth mindset in the metaphorical "mind as muscle" form will provide *better* learning outcomes. All in all, it seems that not only do feedback mechanisms in computer programs matter, but the content, quality, and embedded messages of that feedback also matter. With careful thought, feedback systems can be developed to integrate the "mind as muscle" form of the growth mindset, thereby promoting learning above and beyond what literal feedback about the growth mindset or a simple "correct/incorrect" response could provide.

Third, the reported study found evidence consistent with a commonly noted gendered disparity in statistics and related fields. While females tend to outperform males in mathematics through elementary and junior high school, the trends reverse in high school, college, and beyond (see Hyde, Fennema, & Lamon, 1990 for a meta-analysis). Consistent with these trends, when considering all of the framing conditions, results indicated that males accepted more learning challenges, passed on fewer items, and had better overall performance than females. Given the commonly noted disparity, such a finding seems relatively unsurprising, and appears to confirm the validity of the measures used. However, what does seem surprising is that the results also indicated that when participants were exposed to the metaphorical representation of the growth mindset, outcomes by gender changed. Specifically, although females continued to have lower scores overall than males in the metaphor condition, their acceptance of challenges and number of passes in the same condition did not vary significantly from males, as it had with omnibus testing. That is, the metaphor conditions seemed to place the females on par with males in accepting learning challenges and passing on fewer items. This point may be fairly small in comparison to global attempts to equalize mathematics performance among males and females, but nonetheless, it is a contribution. It may be a small drop in a very large bucket, but the aim and direction of the contribution is noble. In broad terms, what is at stake is that many females who are entirely capable of succeeding in fields of science, technology, engineering, and mathematics (STEM) simply aren't doing so. Some of our brightest minds in these areas may be missing representation in the field because of socially-constructed limitations of their intellectual potential, such as the fixed mindset belief that "women can't do math." This simply is not true. While the metaphor condition was by no means a panacea to resolve gendered disparities, it is promising to consider that presenting the "mind as muscle" metaphor as feedback can encourage equalized performance, albeit in a relatively small and confined context of accepting more learning challenges and passing on fewer difficult items.

Perhaps further applications of the “mind as muscle” metaphor can continue to improve upon these disparities.

Although several important research hypotheses were supported by the empirical evidence, others were not. In particular, hypotheses regarding the impact of framing on the number of passes were not supported. This failure may be due in part to lack of sensitivity in this dependent measure. The purpose of this measure was to gauge performance tenacity. However, there was not any precedent for using such a quantitative measure in research on implicit theories of intelligence. Past research has relied primarily on qualitative evidence such as participants’ comments (e.g., “I’ve almost got it now,” Diener and Dweck, 1978) to assess tenacity. One reason why the current measure might have been ineffective concerns provision of the “pass” or “don’t know” option in multiple answer tests. Given the option, students seem likely to choose a *possibly correct* answer over a *definitely incorrect* one. In this case, options of “pass” or “don’t know” are definitely incorrect. Students may well be acculturated to “choose the best answer.” When they don’t know what the correct answer is, their best guess is to choose from among the remaining responses that might be correct. Given that the “don’t know” or “pass” options are definitely not correct, it seems plausible that participants would not provide those responses, but would rather choose from the other potentially correct options. Providing a “don’t know” or “pass” option seems to have been too weak a measure to evaluate any changes between conditions.

Another hypothesis that was not supported pertained to learners’ sense of being controlled by the computer program. It was proposed that learners might feel a sense of reactance (Brehm, 1966) in response to feedback that explicitly told them to “think more carefully” or “try harder.” Under these circumstances, a “metaphorical sell” of the growth mindset was thought to bypass any potential resistance to the explicit injunctions. However, participants reported equal perceptions of being controlled in all conditions, and being classified in high or low reactance conditions had no notable effect on the learning outcomes. Within the literal and metaphorical conditions, a lack of feeling controlled and subsequent reactance may be due, in part, to participants focusing more on the graphical feedback than the verbal feedback. Participants may have begun to rely more on the spatially salient aspects of the feedback—the avatar working out or not, or the progress box advancing or not—rather than the smaller text box where directive feedback was presented. In this case, it seems plausible that participants would not have felt as if they were being controlled as much by the graphical representations as they might if they focused primarily on the verbal feedback. Perhaps providing verbal feedback in a more salient visual display, or possibly in an auditory mode, would have made the directives more noticeable. A second possibility why the control perceptions did not vary concerns the strength of the manipulation. Language intensity, or the strength of a statement, can affect the persuasiveness of a message. Miller et al. (2007) found that high-controlling language, comprised of phrases such as “should,” “ought to,” “must,” and “need to,” was seen as more threatening to freedom than low-controlling language. It may well be the case that the selected feedback phrases (e.g., “Nope! Work harder!,” “Nope. Keep trying,” or “Incorrect. Don’t give up now!”) were not sufficiently strong to elicit threats to freedom. Perhaps using higher controlling language (e.g., “You should think harder," or "You really need to be more careful") would have strengthened the manipulation sufficiently to garner a response.

A final hypothesis that was not supported pertained to metaphor resonance (Ottati, Rhoads, & Graesser, 1999). According to the motivational resonance model, individuals are more likely to consider a metaphor that resonates with their own interests. In this research, it was proposed that the metaphor condition that equated learning to working out would resonate more with participants who had greater interest in fitness and muscularity, and consequently, would show improved learning outcomes over those with less interest. This was not supported. Interest in muscularity and fitness did not meaningfully change how participants in the mind as muscle condition responded.

At first glance, the resonance finding may seem to be a failed hypothesis. However, the findings that resonance was not supported may actually lend more credibility to using the "mind as muscle" metaphor, as compared to other metaphors that represent growth (e.g., the mind as a seed). As noted previously, participants in the metaphor condition had better overall scores and accepted more learning challenges than those in the other conditions. Thus, participants performed better in the metaphor condition, even though resonance with the metaphor did not affect the outcomes. Why would this be? It is possible that the "mind as muscle" metaphor is conceptually understood by a wide range of people, such that extraordinary interest in and experience with physical workouts are unnecessary to understand the implications of the metaphor. Lakoff and Johnson's (1980) notions of conceptual metaphors may be considered here, inasmuch as metaphor comprehension pertains to experiences that are fundamental to human development. It is not difficult to imagine that all people of sufficient intellectual reasoning would understand—experientially and conceptually—that muscles grow with effort, but do not grow when effort is lacking. Even those who do not workout understand the relationship between effort and developing muscles. In short, the mind as muscle metaphor may be so commonly understood that resonance and active participation in working out are not pre-requisites to understanding and adopting the metaphor's advocated message. Instead of being a flaw of the research, this finding could be interpreted as indicating that the mind as muscle metaphor resonates with a broad range of learners.

Implications

What is the relevance of this research? Consider for a moment that a onetime, 8-10 minute exposure to a learning program can increase non-math major undergraduates' willingness to accept learning challenges in statistics and improve their overall scores on statistical testing items relative to a control condition. Consider also that such a brief exposure to this program might help learners to believe they are capable of learning a difficult subject, and that, like a muscle, their intelligence can grow. And finally, consider that all of this is done without changing any of the testing materials, but rather manipulating the performance feedback provided. Such a program would prove valuable for teaching statistics and other skill-building exercises. The intervention and learning gains mentioned above are not mere possibilities, but rather the outcomes of this research. Although these findings must be considered in the context of the study's limitations, their theoretical and practical significance should not be underestimated.

And, given that such a brief intervention resulted in positive outcomes, the outcomes associated with more prolonged exposure to metaphors of the growth mindset could potentially be substantial.

Theoretically, this research provides a bridge between educational psychology and instructional communication. It presents evidence showing how a theory of learning motivation can be effectively integrated into communication strategies to improve learning outcomes. This study also advances understanding of the role of metaphor in instructional settings. Perhaps the most significant theoretical implication is to begin considering the various functions that metaphors can serve within the learning context. Previous research, as reviewed in the introduction section, has focused primarily on an explanatory function of metaphor, with mixed results. Donnelly and McDaniel (1993), for example, found that metaphors were particularly useful for novice learners, while Rieber and colleagues (1997;1998) found no significant quantitative outcomes when using metaphors in instruction. This research, however, has demonstrated that a metaphor focused on the process of learning, i.e., a motivational metaphor, can be applied to learning materials and effectively increase learner's willingness to accept challenges and their overall scores. Consideration of metaphors related to the process of learning itself may provide outcomes beyond those gained by focusing solely on explanatory metaphors that address a particular context (e.g., metaphors of physics or lightwaves),

A final theoretical implication of this research is that it provides further support for the notion of implicit theories of intelligence, but in a novel context. As a theoretical construct, the learning outcomes associated with implicit theories seem to be well grounded in substantial supporting research (Diener & Dweck, 1978; Dweck, 1975, 1992; Dweck, Chi-yue, & Ying-yi, 1995; Dweck & Elliott, 1983; Dweck & Reppucci, 1973; Dweck & Leggett, 1988; Elliott & Dweck, 1988; Hong, Chiu, Dweck, Lin, & Wan, 1999). The question, then, is how to encourage adoption of the growth mindset? The notion that the growth mindset can be effectively promoted through symbolic representations expands the possibilities and potential of the growth mindset. If promotion of the growth mindset can occur through symbolic forms, what other symbolic forms of the growth mindset might be integrated into learning encounters? Perhaps a class grading system could reflect the assumptions of the growth paradigm: a low-stakes assignment could be presented as a 10-pound workout, while a final exam might be presented as a 150 pound exercise. Rather than a simple letter grade, instructors could evaluate assignments on a "Flabby to Fit" continuum. In place of classroom wall-art that accomplishes no learning objective beyond aesthetics, images of exercise could be connected with messages of learning. An online tutorial might consider using a working-out avatar to represent the progress of the learner. And, instead of being "just a teacher," an instructor could present his or her teaching philosophy as being a "personal trainer, helping you develop a fit mind." To clarify, what is being presented here—though leaning toward practical application—is theoretical consideration of multiple symbolic forms that the growth mindset might take on in instructional settings.

Practically, this study speaks directly to how developers of computer interfaces can build feedback systems that meaningfully improve learning outcomes. Specifically, by designing feedback systems that are grounded in implicit theories of intelligence—the growth mindset in particular—computer program designers may increase the level of challenges learners will accept, and their overall scores. Beyond the growth mindset, developers may be wise to consider the messages that are symbolically encoded in the assumptions of their programs. For example, Re-Mission (hopelab.org, 2006) is a full first-person shooting game designed to teach teenagers with cancer about their treatment. The player is immersed into the inner world—the veins and arteries—of patients with cancer, where they must “power up” with medications, and “fight off” the unwanted cancerous cells by blasting them with chemo-guns. The point here is that the learning game metaphorically equates cancer treatment with fighting a battle. Such a representation may also invite metaphorically-consistent thoughts and frames regarding the treatment, which may or may not be helpful. For example, one implicit message may be that aggressive and invasive treatments are required to win the battle, which may not necessarily be in line with the patients’ self-determination. The notable observation is that assumptions are built into educational computer programs. Awareness of those assumptions, followed by program modifications in line with rigorous established research, can lead to the development of programs that more effectively promote learning.

Another practical implication of this research, as mentioned previously, is to consider more broadly how the growth mindset can be integrated into various instructional practices. While this research addressed only a computer program, various alternative approaches to encourage adoption of the growth mindset might also be effectively considered.

Limitations and Future Directions

There are many limitations to this project. First, the method for assessing acceptance of challenges may have created confounds in the experimental design. Following each phase, participants were asked if they wanted the next phase to be easy, moderately difficult, or difficult. The subsequent phase, however, did not change according to their response. This is likely to have created some problems within the experimental design. For example, if an individual chose "Easy" following the first phase, they might be expecting an easier set of items. In fact, they were exposed to the most difficult questions of all in Phase 2, as well as the series of "incorrect" responses that comprised the planned failure. Given that such participants wanted Phase 2 to be easy, and they were told they did not do well on Phase 2, it would be logical to assume that they would not want to choose a more difficult option. Consequently, they would seem more likely to again choose the "Easy" option following Phase 2. Thus, the measure for accepting challenges may have been compromised by the fixed order of the phases, while participants may have believed the order of the phases was dependent on their responses.

A second limitation, as mentioned previously, concerns the measurement of control perceptions. While the experimental conditions may not have been sufficiently directive or forceful enough to elicit reactance, another possibility is that the measure was simply not sensitive enough to pick up on perceptions of control. Although based on the work of others, the perceptions of control measure used in this context was a first attempt that seemed to lack refinement.

A third limitation to consider is the potential impact of different depictions of fitness and muscularity presented to male and female participants. The difficulty here was that fitness and muscularity may look very different according to gender. Males are more likely to be interested in developing muscular size (e.g., Mishkind, Rodin, Silberstein, & Striegel-Moore, 1986), whereas females tend to be more interested in becoming more trim and toned (e.g., McCreary & Sasse, 2000). The challenge, in particular, was that creating a female avatar that became increasingly muscular could have cast an extreme highlight on a form of muscularity that did not conform to social norms, and may have elicited some sort of negative response. That is, it is possible that many female participants would not have found a highly muscular female avatar to be reinforcing. Given these possibilities, the metaphorical condition for males reflected notable muscular growth while the metaphorical condition for females reflected very slight muscular growth. If muscularity—in the sense of getting bigger, larger muscles—was a critical component in the advocated growth metaphor, the experimental manipulation may have favored males. However, even the idea of becoming “too muscular” may also carry social implications related to lower intelligence. That is, just as female muscularity may carry a negative social response, likewise, excessive male muscularity may elicit a “dumb jock” stereotype, wherein too much muscularity is associated with poor intelligence. Although no mediational effect was found for fitness or muscularity, careful consideration of the metaphor may still necessitate attention. The critical point here may be in the necessity of distinguishing “muscularity” from “fitness,” or in creating a true hybrid of a moderate representation of “working out” as the metaphor. Thus, the metaphor may not be so much about the “mind as muscle” as it is a “learning as working out” metaphor.

A fourth limitation is the potential motivation that may have arisen from the animation format used in the metaphor condition. Specifically, the metaphor condition was comprised of the testing area, the progress bar, and the animation sequence. The interface itself may have been more engaging and stimulating than the other conditions, which did not include any animated sequences. As a result, the positive learning outcomes associated with the metaphor condition may have been attributable, in part, to motivation and increased interest resulting from a more exciting, engaging interface. The desire to see the next animated sequence may have been more motivational to participants than the actual content of the animation itself. Such added interest is worthy of further consideration, given that the use of animations alone could have contributed to accepting more challenges and improved scores.

A final limitation of this research is the premise that this study was about motivating students through integration of metaphors in the *learning* process. In fact, the computer interventions presented participants with a series of testing questions. Consequently, and more accurately stated, the research was about motivating students through metaphors in a *testing* environment. Motivation is central to both learning and testing. However, the distinctions between the processes of learning and testing are important, given that learning is primarily a process of *acquiring* new knowledge or skills, while testing is primarily a process of *evaluating* how much knowledge or skill has been acquired. As noted by Elliott and Dweck (2008), learning outcomes may change based on whether or not a student feels he or she is engaged in an activity to acquire new information (e.g., a mastery orientation) or is being evaluated on information already acquired (e.g., a performance orientation). Thus, a student may be motivated to learn, but subsequently may experience anxiety during testing that could compromise the outcomes. The outcomes for such a student may vary widely, depending on whether the student is framing a given exercise as a learning activity or a testing activity. The reported results of this project, then, are perhaps more appropriately interpreted as the results of encouraging the growth mindset within the context of testing, rather than learning.

In addition to considering the particular metaphorical representation of growth, there are multiple future directions to consider with this research. First, as has been previously mentioned, what other formats can instructors use to symbolically represent the growth mindset, and to what effect? The metaphor of choice for this research was the muscular mind. Promoting growth within this metaphor might be considered in various forms. For example, can the growth mindset be encouraged by the presence of a physical object that reflects the muscular mind, such as weights, or elements of a workout environment? Other metaphors of growth might also be considered. For example, how might metaphorically equating learning to growing plants compare to the muscular mind metaphor? Or, consider the implications of an architectural metaphor of the mind, wherein learning is conceptualized as building a structure. Another medium for encouraging the malleability of intelligence might be through kinesthetic, tactile interventions that symbolically represent the plasticity of the mind, such as inviting participants to hold a silly putty-like model of a brain in their hands while they take the tests, versus a hard, fixed metallic brain model.

While various metaphors could be considered, it is noteworthy to contemplate the effectiveness of particular metaphors at different stages of learning. For example, Donnelly and McDaniel (1993) found that metaphors promoted greater recall for teaching novice learners basic concepts than for advanced learners. While advanced learners may feel they are "beyond the trifling" of metaphors, the issue may be that different metaphors suit learners differently at different stages. Thus, a motivational metaphor may be more appropriate at the beginning of a student's learning process, but may be supplanted by explanatory metaphors as conceptual understanding increases. And, lastly, perhaps a category of "mastery metaphors," or metaphors that emphasize the mastery component of the growth mindset would be more appropriate (e.g., "You really owned that topic!" or "That was a piece of cake for you"). Developing strategies for *when* to implement *which* metaphor might help instructors to more effectively meet the needs of their students at different levels of learning.

Another important step will be to assess the efficacy of the "mind as muscle" metaphor among different participant age ranges. Specifically, taking similar research to elementary and junior high school students could be very beneficial, especially if the growth mindset could be encouraged at a younger age. Senior citizens would also be a very important population to study. Assessing the effectiveness of the "mind as muscle" metaphor among senior citizens could potentially encourage mental acuity, foster cognitive agility, and help them maintain a “fit” mind, leading to an increased quality of life well into their later years.

Finally, extending beyond the context of metaphors of growth in educational computer programs, research can be furthered regarding the persuasive use of symbolic messages that undergird the development of various media. Such research could integrate well with the work of Reeves and Nass (1996) and others (e.g., Fogg, 2003) who are interested in communication technology and the social implications of interface design. Bogost, for example, has (2005) indicated that some internet-based videogames have used metaphorical messages to make political statements. For example, the *Tax Invaders* game developed by the GOP portrayed missiles shooting out of then President George W. Bush’s head, targeting blocks of numbers identified as presidential candidate John Kerry’s tax ideas. The metaphorical messages—of invaders, aliens, heroes, and dangerous villains—were all embedded symbolically in the programming. As multimedia platforms continue to be developed, they will each carry embedded symbolic messages that reflect the assumptions and motives of their developers. This project has shown that symbolic, implicit messages can be integrated successfully into a media platform to improve learning outcomes. Further research regarding the strategic use of symbolic communication in mediated communications may contribute meaningfully to questions—and solutions—about the influence of media in society.

Table 1

Effects of Framing Condition on Learning Outcomes

Learning Outcome	Framing Condition					
	Control		Literal		Metaphor	
	M	*SD*	*M*	*SD*	*M*	*SD*
Accept Challenges[a]	4.825	1.39	4.702	1.43	5.636	1.68
Number of Passes[b]	0.553	0.72	0.721	0.73	0.504	0.64
Total Score[c]	9.178	2.42	9.554	2.15	10.669	2.29

Note. Columns contain mean scores (*M*) and standard deviations (*SD*). Accept Challenges[a] is out of 9 possible points. Number of Passes[b] is out of 18 possible points, and Total Score[c] is out of 18 possible points.

Table 2

Effects of Framing Condition by Gender on Learning Outcomes

Learning Outcome	Framing Condition					
	Control		Literal		Metaphor	
	M	*SD*	*M*	*SD*	*M*	*SD*
			Males ($n = 61$)			
Accept Challenges[a]	5.605	1.31	5.149	1.34	5.521	1.61
Number of Passes[b]	0.383	0.69	0.58	0.60	0.267	0.59
Total Score[c]	9.288	2.25	10.434	1.70	11.964	1.76
			Females ($n = 63$)			
Accept Challenges[a]	4.045	0.97	4.255	1.32	5.751	1.80
Number of Passes[b]	0.723	0.75	0.862	0.82	0.741	0.67
Total Score[c]	9.069	2.64	8.675	1.98	9.374	2.14

Note. Columns contain mean scores (*M*) and standard deviations (*SD*). Accept Challenges[a] is out of 9 possible points. Number of Passes[b] is out of 18 possible points, and Total Score[c] is out of 18 possible points.

Figure 1. Computer interface for the Control framing condition.

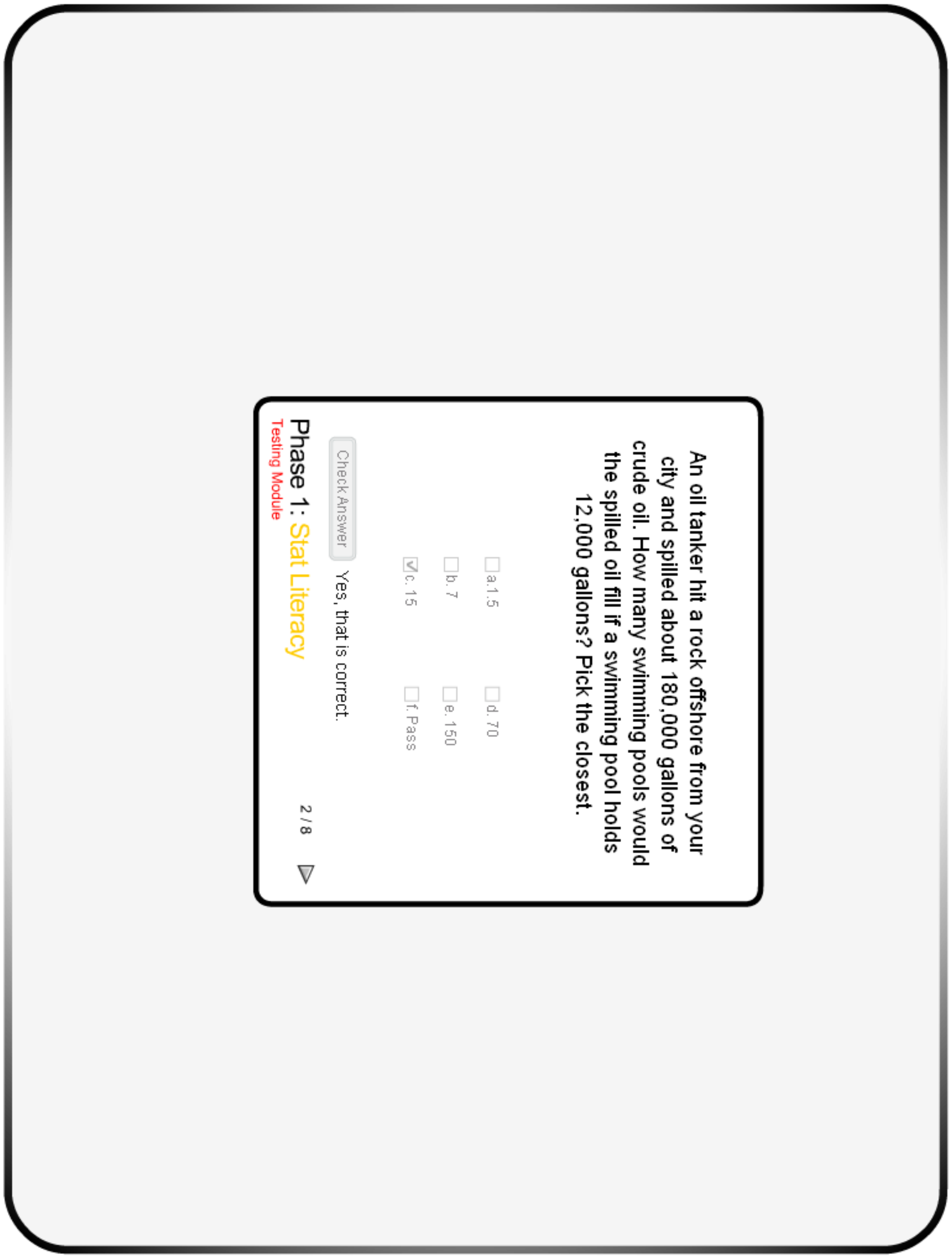


Figure 2. Computer interface for the Literal framing condition.

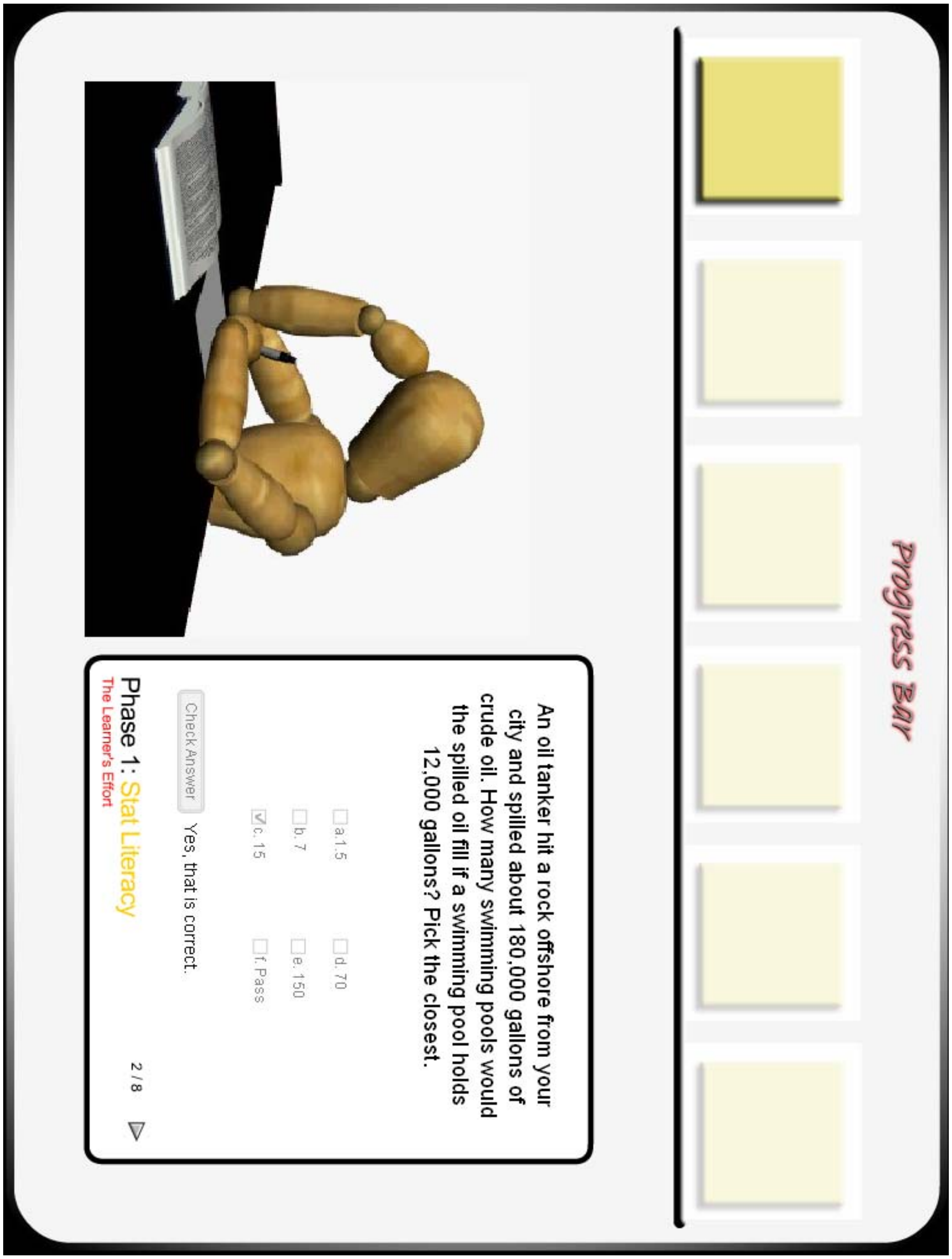
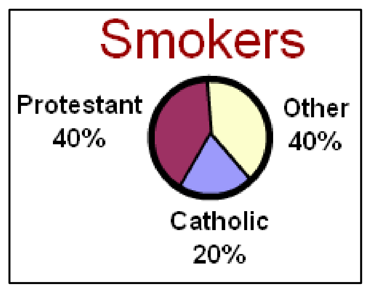


Figure 3. Computer interface for the Metaphor framing conditions.

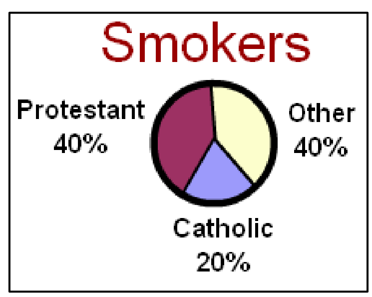
Appendices

Appendix A: Statistical Literacy Items
(Items adapted from Schield's Statistical Literacy Survey, V2, 2008)

1. An oil tanker hit a rock offshore from your city and spilled about 180,000 gallons of crude oil. How many swimming pools would the spilled oil fill if a swimming pool holds 12,000 gallons? Pick the closest.
   a. 1.5
   b. 7
   c. 15
   d. 70
   e. 150
   f. Pass
2. The budget was cut from \$2 million to \$1.5 million. What was the percent change? Pick the closest.
   a. 75% decrease
   b. 25% decrease
   c. 33% decrease
   d. 33% increase
   e. 25% increase
   f. Pass
3. If Jay is older than Tom and Nan is younger than Jay, then Nan must be older than Tom.
   a. True
   b. False
   c. Pass
4. Does this statement adequately describe this pie chart? "The percentage of smokers who are Protestants is 40%."
   a. Yes
   b. No
   c. Not enough information
   d. Pass



5. Does this statement accurately describe the comparisons within this pie chart? "Smokers are more likely to be Protestants than to be Catholics."
   a. Yes
   b. No
   c. Not enough information
   d. Pass



6. Your city of 150,000 had a total of 75 murders last year. What was the murder rate per 100,000? Pick the closest.
   a. 30
   b. 50
   c. 75
   d. 150
   e. 500
   f. Pass

7. If incomes of rich and poor people both increase at the same rate, the income gap between rich and poor
   a. Will decrease.
   b. Will stay the same.
   c. Will increase.
   d. Don't know.
   e. Pass

8. Which of these is an accurate comparison for these fish?
   a. Salt-water fish are more likely among night- than day-feeders.
   b. Night-feeders are more likely among salt- than fresh-water fish.
   c. Either of the above (both are OK)
   d. None of the above.
   e. Don't know.
   f. Pass

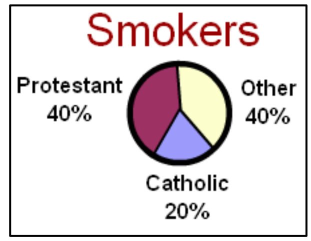
Fish	**Habitat**		
Feeding Time	*Fresh Water*	*Salt Water*	ALL
Night	35%	70%	55%
Day	50%	25%	35%
Other	15%	5%	10%
ALL	100%	100%	100%

9. Eight is 300% more than two.
   a. True
   b. False
   c. Don't know
   d. Pass
10. For any group of adults, the "percentage of adult smokers who are female" is ALWAYS more than "the percentage of adults who are female smokers."
    a. True
    b. False
    c. Don't know
    d. Pass
11. Two is four times less than eight.
    a. True
    b. False
    c. Don't know
    d. Pass
12. A company has a 30% market share in the Western US and a 10% market share in the Eastern US. What is the company's overall market share in the entire US?
    a. Between 10% and 30%
    b. 30%
    c. Between 30% and 40%
    d. 40%
    e. Over 40%
    f. Pass
13. Refer to the chart below. Suppose we define 'Rich' as \$75K and up and define 'Poor' as under \$25K. Based on family income, who had the most pets: rich households or poor households?
    a. Rich households
    b. Poor households
    c. The same
    d. Don't know
    e. Pass

Table 1: US Households (in millions) who had a pet in 2004 by family income

<10K	10K – 19.9K	20K – 24.9K	25K – 29.9K	30K – 34.9K	35K – 49.9K	50K – 74.9K	75K >	TOTAL
4.2	6.2	3.4	3.8	3.6	8.9	10.6	12.5	53.2

14. Does this statement accurately describe the comparisons within this pie chart? "Protestants are more likely among smokers than are Catholics."
    a. True
    b. False
    c. Not enough information
    d. Pass



15. Your city has a property tax rate of $10 per $1,000 assessed value (but $50,000 of the home value can't be taxed because of the state's homestead exemption). What would be the tax bill for a typical homeowner if the median assessed value of homes is $250,000?
    a. $200
    b. $500
    c. $2,000
    d. $2,500
    e. $20,000
    f. $250,000
    g. None of these
    h. Pass

16. Last year's budget was $4 million; this year it's $4.4 million. How does this year compare with last year as a percentage change? Pick the closest.
    a. $400,000 increase
    b. 4% increase
    c. 10% increase
    d. 40% increase
    e. 110% increase
    f. Pass

17. If a stock increases 50% and then decreases by 50%, it will be back to its original value.
    a. True
    b. False
    c. Pass

18. If profits drop by $600,000 from +$300,000 to -$300,000, that is a 200% decrease.
    a. True
    b. False
    c. Pass

Appendix B: Measures

Implicit Theory of Intelligence (from Hong, Chiu, Dweck, Lin, & Wan, 1999)

Please rate your disagreement or agreement with the following statements, ranging from "Strongly Disagree" to "Strongly Agree". (On 6-Point Likert scales)

1. You have a certain amount of intelligence and you really can't do much to change it.
2. Your intelligence is something about you that you can't change very much.
3. You can learn new things, but you can't really change your basic intelligence.

External Control Perceptions

Please use the following scales to indicate the degree to which you disagree or agree with the following statements. All statements are in reference to the computer program you just used. (Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree)

1. The computer program was trying to control how I answered the questions.
2. The computer program was trying to control what I thought.
3. The computer program tried to make me work too hard.
4. The computer program tried too hard to motivate me.

Hong Psychological Reactance Scale (Hong & Page, 1989)

Please use the following scales to indicate the degree to which you disagree or agree with the following statements. (Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree)

1. Regulations trigger a sense of resistance in me.
2. I find contradicting others stimulating.
3. When something is prohibited, I usually think "that's exactly what I'm going to do."
4. I consider advice from others to be an intrusion.
5. I become frustrated when I am unable to make free and independent decisions.
6. It irritates me when someone points out things which are obvious to me.
7. I become angry when my freedom of choice is restricted.
8. Advice and recommendations induce me to do just the opposite.
9. I resist the attempts of others to influence me.
10. It makes me angry when another person is held up as a model for me to follow.
11. When someone forces me to do something, I feel like doing the opposite.

General Fitness and Muscularity

<u>Fitness</u>
Please indicate how much you disagree or agree with each statement below. A rating of "-3" indicates that you Strongly Disagree with the statement, while a rating of "+3" indicates that you Strongly Agree with the statement. Any number between—-2, -1, 0, 1, 2—may also be used to indicate an intermediate level of disagreement or agreement.

1. Presently, I am in excellent physical shape.
2. At this time in life, a regular workout routine is extremely important to me.
3. At this time in life, I am highly committed to being in good physical shape.
4. When I exercise, I usually have as much energy and stamina as I need.
5. Physical fitness is an extremely high priority for me in my life right now.
6. On average, how many days per week do you workout? (0-7)

<u>Muscularity</u> (selected from Markland and Hardy's (1993) Exercise Motivation Inventory)
Please indicate how untrue or true each statement below is regarding your reasons for exercising, or what your reasons might be for exercising if you currently are not exercising. A rating of "-3" indicates that the statement is not at all true for you, while a rating of "+3" indicates the statement is very true for you. Any number between—-2, -1, 0, 1, 2—may also be used to indicate an intermediate level of "true-ness."

Personally, I exercise (or might exercise)...

1. to achieve greater muscle mass.
2. to become strong and powerful.
3. to tone and define my muscles.
4. to increase my body size.

Attitudes Toward Statistics (adapted from Wise's Attitudes Toward Statistics Scale, 1985)

Please indicate how much you disagree or agree with each statement below. A rating of "-3" indicates that you Strongly Disagree with the statement, while a rating of "+3" indicates that you Strongly Agree with the statement. Any number between—-2, -1, 0, 1, 2—may also be used to indicate an intermediate level of disagreement or agreement.

1. I feel very comfortable with formal statistics (e.g., chance, probability, sampling distributions, confidence intervals, etc.).
2. I feel that statistics will be useful to me in my profession.
3. The thought of being enrolled in a statistics course makes me nervous. (R)
4. I am excited about the possibility of actually using statistics in my job.
5. Studying statistics is a waste of my time. (R)
6. I would like to continue my statistical training in an advanced course.
7. Statistics seems very mysterious to me. (R)

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